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## Forthcoming Events.

JULY 4 to 9.

*Society of Chemical Industry*:—Forty-sixth annual meeting to be held in Edinburgh.

JULY 5-8.

**Institute of British Foundrymen.**

Conference at Sheffield.

**THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.**

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## The Foundry and the Engineer.

We publish this week an article written by an engineer using the *nom de plume* "Progrés." Whilst the matter exposed does not add largely to the founder's stock of knowledge, it has real importance as showing how interested engineers are regarding the foundry industry. It is patent that our contributor has been in touch with the exploiters of the latest developments and has assimilated much of their arguments. Thus, the question obviously arises: Is he typical of the average progressive engineer? Probably he is metallurgically more erudite than the average, but we do find that engineers in general, being unable intelligently to follow the latest developments, have confidence that real progress has been made, and that they are prepared to try out the higher grades of iron, *but* at pretty well all the same old starvation prices. When the founder objects, he merely retorts that foundry prices are fictitious, owing to internal extravagance with transport, fuel and labour. This is precisely the point at which "a little knowledge is a dangerous thing." Primarily it is the engineer's duty to the founder to provide as he has done in the case of the brewer, the miller and the collier, an efficient transport system, modified to meet the exacting conditions of the industry. With a few brilliant exceptions, engineers in general have done nothing to mechanicalise foundry practice, and it has been left very largely to the foundryman to teach the engineer his job. "Progrés" has made an initial mistake in starting off with the cupola, for it should be an engineer's job to ensure that the foundry has his material delivered inside the cupola at the lowest possible cost. This subject has been successfully tackled by diverse foundry engineers, who have graduated in the foundry itself.

The developments which "Progrés" has stressed are all the result of enterprise by the foundryman. The sand slinger and the majority of the moulding machines have been invented by foundrymen.

We recently emphasised the value of foundry papers being presented to engineering societies, but there is just the possibility that the result may be that their present unbalanced ideas may be thrown still further out of balance.

They may hear in the near future that tests of over 40 tons per sq. in. tensile have been obtained from special grey iron experimentally, and may expect this from a jobbing foundry with a preference for "chunking" castings. Further, having had it well drilled into them by certain members of the foundry industry that most founders are incapable of clear thinking, they will not be in a great hurry actively to co-operate in order that steady progress may be made, but will prefer to dominate without real knowledge, as he has done for many years. There is at present a case under discussion, wherein a certain mixed committee of engineers and founders are drawing up a specification, certainly based on the foundrymen's findings, but the former are trying to insist that the latter guarantee their castings for a very considerable period. Surely the engineering profession is not so poorly equipped mentally that it requires, after inspecting and passing a casting, additional guarantees from the foundry to compensate them for their own ignorance. We are aware that there may be hidden flaws in castings, but there always were, and probably always will be, and so factors of safety must be allowed, depending not merely upon increased sections, but based upon modern foundry data. Though "Progrés" hits fairly hard, he shows more understanding of the foundry industry than his confrères.

# Correspondence.

*[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]*

### Progress in Iron-Founding.

*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—Mr. Shaw's letter in your issue of the 9th inst. and Mr. Young's reply in this week's are most interesting.

The excellent discussion in connection with pearlitic cast iron—or, as Mr. Young has christened the method of casting into heated moulds, the "Perlit" process—has proved most satisfactory to the British metallurgist, for it has brought out the fact that heated moulds were being used, and were, in fact, discarded after the erection of expensive plant to carry out the process, before the "Perlit" process was experimented with and adopted in Germany. Hence when the process of heated moulds was brought over to this country it was not new here, and, in fact, heated moulds have been used in poor old England for 60 years or more. The British foundryman has therefore scored again and is not, as Dr. Carpenter's Paper suggests, behind his Continental *confrère*.

In the second paragraph of his letter Mr. Young suggests that an all-pearlitic structure *might* be found in any old piece of stove-grate iron, but surely he has been misinformed, for if a mixture of irons which would give a pearlitic structure in such light castings were to be used in stove-grate work, it is most probable that 90 per cent.—or even more—of the castings would be wasters. Stove-grate iron requires to be softer than would give an all-pearlitic (not Perlit) structure.

In the third paragraph of his letter Mr. Young apparently wants to specify to Mr. Shaw a "*Perlit*" *mixture* to obtain a pearlitic *structure* without the moulds being heated, although he must know perfectly well that a "Perlit" mixture, if cast into a cold mould, would be either mottled or white iron. Let us be fair, and if Mr. Shaw wishes to take up the challenge, give him the opportunity of putting up a mixture of grey irons which would give the pearlitic structure if cast into a cold mould as he himself suggests. What Mr. Shaw is undoubtedly referring to is a *pearlitic structure, not a "Perlit" mixture* cast into a cold mould.

Mr. Shaw is quite right, as every practical iron-founder knows, it is not commercially or otherwise economically practicable to use the "Perlit" process in making large turbine casings. Further, it may interest your readers to know that recently friends of mine were quoted about 40 per cent. more for "Perlit" castings than for ordinary.

It is very satisfactory to know that Mr. Young has an open mind with regard to "alloy" irons, and that these will benefit the "perlit" process, as well as pearlitic cast iron obtained by non-"perlit" methods.—Yours, etc.,

E. ADAMSON.

Sheffield, June 19, 1927.

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*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—If Mr. Young had given definite replies to the points raised in my letter in your issue of June 9 his answer would have been of general interest. But it contains the usual vague and nebulous statements one is accustomed to in regard to the material in question. From his remarks about "any old piece of stove grate, etc.," I take it he is in agreement that it is possible to have an all-pearlitic structure (except graphite, etc.) and yet a weak iron. With regard to the second point, I was not concerned with a "Perlit specification," but with an iron that would give small growth and fair physical results at 500 deg. C. I gave credit to the hot mould process because it was possible to have a very low silicon and yet produce a machinable casting (in the light of Dr. Andrews' Paper of last week before the A.F.A. even this advantage is only one of degree), but suggested, from experiments carried out, that other methods might give equal results. Has it yet been proved from actual working conditions what is to be gained from the hot mould process? Has any Diesel engine been fitted with part hot mould cylinders and one or more with a pearlitic structure obtained from composition alone? If so, what is the actual difference in wear and growth over a period?

My third point was not answered. There is one firm, if not more, who are making turbine casings of the type I mentioned under a "Perlit" licence. Do they re-heat up their moulds (not merely warm) so as to use an approximate 0.7 per cent. Si and obtain a machinable casting?

With regard to the fourth issue raised, Mr. Young conveniently ignores the latter half of the sentence. He quotes, "*and the English company had a slight advantage in the physical tests.*" Here again can Mr. Young or his *confrères* point to a definite trial where, say, a pair of high-speed engines running parallel off the same steam main, one set fitted with hot mould cylinders, the other with a pearlitic structure arrived at by composition? If so, what gain in wear or other advantages were claimed? The patent for "Perlit" goes back eleven years. Surely some definite mechanical data have been collected during that time. I know certain information on this point has been given, but the composition and structure of the castings I saw were such that no other result could be expected. If it would not be a breach of confidence, could Mr. Young give us the difference in growth and wear between the excellent Diesel liners he made before adopting "Perlit" and the same type liners cast by the "Perlit" process? We are already heavily handicapped in this country with high rates and taxation, and pay higher wages and work shorter hours than our Continental rivals, that some definite advantage must be proved before adding another 10 per cent. to foundry production costs plus a royalty.—Yours, etc.,

J. SHAW.

Brightside Foundry, Sheffield, June 18, 1927.

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### Laboratories of Beecroft & Partners, Limited.

*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—There must be many chemists who, like myself, have been greatly interested by the article on "Laboratories and Works of Beecroft & Partners, Limited," in your current issue. There are in it several points calling for attention, and particularly with regard to the combustion carbon apparatus used.

(1) Use of lead chromate.—There is no note that a weighed quantity of this is used. Do Messrs. Beecroft & Partners not find that their blank varies if the amount of this material is not kept constant?

(2) Time required.—It would be interesting to know what weight of sample Messrs. Beecroft & Partners use, also whether they take any special precautions as to the form of the drillings, and at what rate oxygen is passed through the train. Eight minutes certainly seems to be a very short time, and in the writer's experience when using .6818 grm. of sample, something like twice this time, or even more, is necessary to make quite sure of complete combustion.

If estimations are made in eight minutes, the furnace is presumably not allowed to cool down before introducing a fresh boat.

The writer has found it advisable to let the temperature drop to 700 deg. C. between estimations when analysing irons containing appreciable proportions of graphite carbon, otherwise a slight amount of graphite will be burnt almost immediately the boat is introduced, and a little of the resultant $CO_2$ lost before it has been possible to close up the train.

(3) Lines 15-16, page 504, state: "It will be noted that there is no spraying," etc., and the writer would be grateful if some further explanation of this passage could be given.—Yours, etc.,

"WORKS CHEMIST."

Llanelly, June 18, 1927.

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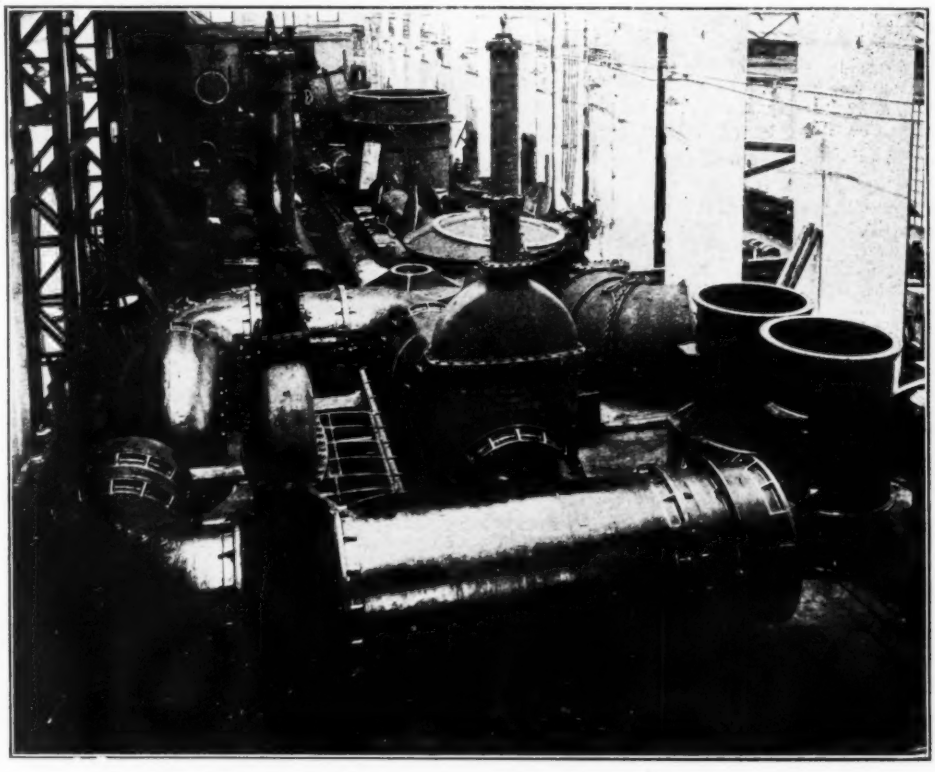
**Chrome-Nickel Steel.**—The International Nickel Company of Canada, Limited (Port Colborne, Ontario), have issued a small pamphlet under the title of "Chrome Nickel Steel in Special Track Work." It discusses the characteristics of this grade of steel, and gives the results of more than six years of its use by the Milwaukee Electric Railway and Light Company.

# A Notable Example of Foundry Work.

BY OUR ENGINEERING CORRESPONDENT.

We reproduce herewith a photograph of a very large cast-iron pipe equipment, with valves and other accessories, recently supplied by Glenfield and Kennedy, Limited, of Kilmarnock, to the Electricity Department of the Borough of Woolwich, in connection with cooling water at their electricity station. This is an excellent example of good foundry work, the photograph showing the installation assembled for test at 50 ft. head in the shops at Kilmarnock, and the breeches piece alone, for example, weighs 17 tons. In this work at Woolwich, the chief consultant has been Mr. H. H. Ryder, of Preece, Cardew and Ryder, of London, while the estimates were checked by Mr. Basil Mott, of Mott, Hay and Anderson, Limited, the civil engineering was undertaken by the Foundation Company, Limited, of London, and all the valves, pipes and similar equipment necessary were supplied by Glenfield and Kennedy, Limited.



A LARGE CAST-IRON PIPE EQUIPMENT MADE BY GLENFIELD & KENNEDY, LIMITED.

The source of the water is the River Thames, which is tidal at this point, and three shafts were sunk, one being on the river bank, 60 ft. deep and 24 ft. in diameter, while the other two in the river bed itself, at about 30 ft. centres, being 15 ft. diameter. These shafts are all connected by a horizontal tunnel 220 ft. long and 9 ft. 6 ins. diameter, built up of cast-iron segments lined with concrete, divided longitudinally into two parts, each semi-circular in form, by a vertical wall or diaphragm, or reinforced concrete. The ends of these two conduits in the shaft sunk on the shore are controlled by two hydraulically operated single-faced sluice valves, while it is also possible to reverse the direction of the flow, using first one conduit for the inlet and the other for the discharge, and then changing over, in this way clearing away immediately any mud or other obstructions, especially on the grids which cover the ends of the shafts.

The capacity of each of these conduits is 3,500,000 galls. of water per hour at an average velocity of 5.3 ft. per sec., while further the upstand pipes or vertical portion of the circulating water system are of cast iron, 5 ft. in diameter, and 1¼ ins. thick, being bolted at the bottom to the cast-iron "breeches" pieces mentioned, each section of which is closed by a sluice gate.

The sluice gates are of cast iron, with gunmetal faces riveted to the doors, machined and adjusted to make watertight contact with corresponding gunmetal faces riveted to the frame, while the doors are heavily ribbed in order to strengthen them. Further these sluice gates on the general principles of design adopted by the firm are operated by an independent hydraulic cylinder with a working pressure of 220 lbs. per sq. in., the design allowing for easy opening no matter what mud and silt may have accumulated. The very large valves used on the circuit are 60 ins. diameter, of the bye-pass sluice type, being the standard 4-face design, with tapering doors and bronze faces, hydraulically operated by a super-imposed cylinder working at 220 lbs. per sq. in. as before, all the working surfaces being lined with bronze, while the sliding spindles are of special high tensile forged bronze. Also the operating or "Pilot" valves, one for each sluice, are fixed on cast-iron standards at the operating floor level, and these are of the 4-way type, hand-controlled locking gear being provided so as to prevent either the sluice doors or the sluice-valve paddles from closing by their own weight should the hydraulic pressure fall by any chance when they are in the open position. Glenfield and Kennedy, Limited, have, of course, had very extensive experience in this particular field of cooling water supply for power stations, and they have, in fact, just recently received an order for three 48 in. by 60 in. double faced taper steel sluice gates for the Congella Power Station, South Africa, as well as two special 60 in. cast-iron double-flanged sluice valves for the Barking Electricity Station.

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**Canadian Steel Industry.**—A decided forward movement is shown in the iron and steel industry in Canada, the output of pig-iron in March showing a gain of almost 50 per cent. over February, the figures being: March, 75,637 tons; February, 50,695 tons of 2,240 lbs. With the exception of March, 1924, when there was an output of 77,290 tons, the output in March of this year was the greatest recorded in that month in any year since 1920. Basic pig-iron produced mostly for further use by the makers accounted for the increase.

# The Growth of Cast Iron.*

By Dr. J. H. Andrews, D.Sc., Glasgow.†

A glance at the bibliography relating to published researches on the growth of cast iron might give the impression that this problem had been thrashed out in every detail. A perusal of the original papers, however, cannot but impress one with the conflicting results and opinions of the different authors. It is therefore with a view to summing up the conclusions of the different investigators and of putting forward certain reasons for the many discrepancies that this Paper is written.

### Researches of Okochi and Sato.

Probably the first systematic work carried out on the growth problem was that of Okochi and Sato,[1] who, using a dilatometric method of experimenting, came to the following conclusions:—

(1) Oxidation does not play an important part in the growth.

(2) Decomposition of cementite is partially responsible for growth.

(3) The gas pressure within the metal is an important feature.

### Carpenter and Rugan Findings.

Following up the work of Outerbridge,[2] Carpenter and Rugan[3] carried out exhaustive experiments with special iron in which silicon and other elements were allowed to vary, one at a time. Their conclusions were:—(1) Growth is largely due to the oxidation of the silico-ferrite; (2) graphitisation of the cementite is partially responsible for growth; (3) phosphorus, and especially manganese, diminish growth, and (4) a white iron will not grow so long as it remains white.

### Dilatometric Test Results of Kikuta.

In 1922 Kikuta[4] published his results obtained by using a dilatometric method similar to that of Okochi and Sato. From leakage tests carried out to determine the evolution of gas from the specimen at different temperatures and after different heatings, he found that the leakage rate increased slightly with the temperature for the first twenty-one heats, and increased with the numbers of heatings up to about sixty heats. From these experiments he concluded that gas pressure cannot be regarded as being responsible for much of the growth. From the results of his dilatation experiments he concluded that:—(1) Graphitisation of cementite brings about a certain amount of growth during the first heating; (2) indirect oxidation in which the oxide when formed fills the fissures and cavities during the $A_1$ transformation is partially responsible for growth; and (3) the greater part of the expansion is due to the minute cavities or fissures formed by the irreversible expansion in different microportions of the specimen.

Curiously enough, he states that the elongation observable at temperatures above $A_1$ is due to the presence of occluded gases, as conceived by Okochi and Sato. The oxidation theory of Carpenter and Rugan is, he says, untenable.

### Conclusions Reached by Andrew and Hyman.

Andrew and Hyman,[5] using a method similar to that of Carpenter, came to the following conclusions:—(1) The growth of cast iron takes place in two stages. The first is the rapid stage, and is due to oxidation of the ferrite. The second stage, *i.e.*, the slower stage, is marked by a rapid oxidation of the free graphite, which is replaced by oxide metal; and (2) from their experiments on nickel iron in which the permanent growth was as pronounced as it was in the silicon irons they suggested that the influence of such graphitising elements as silicon aluminium and nickel was by virtue of their effect upon the form of graphite, which on account of their presence existed in the form of very large and thick flakes. The penetration of gas through a large and thick flake would take place more easily than it would through a thin one.

The most recent work is that of Pearson.[6] This author, after carrying out experiments similar to those of Carpenter, supports the latter author in most of his conclusions. He further confirms the work of Andrew and Hyman in that the form of the graphite flake influences the rate of growth. Andrew and Higgins,[7] using a form of dilatometer different from that of the Japanese workers, carried out a series of tests on irons which varied in manganese and phosphorus. Since the conditions under which these experiments were performed are peculiar to themselves, this work will be dealt with later.

### Research Workers draw Varying Conclusions.

This brief summary of work done is sufficient to show that while certain conformity of viewpoint does exist, the different workers are by no means unanimous in their opinions.

Most of the investigators in this field agree that graphitisation is responsible for a certain part of the growth. Moreover, the results of the many observers who have conducted growth experiments in vacuo all seem to point to the necessity of air or an oxidising gas as being an instrumental factor. This is further substantiated by Pearson, who found that only a slight permanent expansion occurred after conducting the heating in an atmosphere of hydrogen.

Although the Japanese workers would seem to regard oxidation of the ferrite as a secondary factor, the experiments of Carpenter, Pearson, Andrew and Hyman strongly point to this reaction as being a primary factor. Further, Pearson, by using a carbon dioxide atmosphere in place of air, found much greater growth. In favour of the oxide theory may be cited the following proof:—(1) The irons of Carpenter high in silicon eventually disintegrated; this is strong evidence of the formation of some other material such as iron or silicon oxide forming within the specimens. This worker along with Pearson, and Andrew and Hyman, further found an increase in weight corresponding to the increase in volume. It is obvious that the only material that could be added in these experiments is oxygen. Pearson, on separating the silicon from the silica in his treated specimens, found that silicon became changed into silica as the number of heatings increased.

Andrew and Hyman found that after fifty heats certain of their irons showed a complete absence of carbon, each graphite flake being oxidised and its place taken by oxide of iron, which, when separated and analysed, was found to have the composition of $Fe_3O_4$. The presence of oxide as a micro constituent was further confirmed by Andrew and Higgins.

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* This Paper is one of a series on foundry problems being exchanged between the Institute of British Foundrymen and the American Foundrymen's Association. The first, prepared by the late George K. Elliott, was presented at the 1921 meeting of the Institute of British Foundrymen. The second was presented at the Rochester, New York, meeting of the American Foundrymen's Association by F. J. Cook, Past-President of the Institute of British Foundrymen. Professor Enrique Touceda presented the third paper before the British Institute. The fourth was written by Dr. Percy Longmuir; the fifth by Major R. A. Bull; the sixth by Wesley Lambert and G. Hall; the seventh by Dr. R. J. Anderson and M. E. Boyd; the eighth by J. E. Fletcher; the ninth by Dr. H. Ries; the tenth by Arnold J. Lenz; the eleventh by John Shaw. This, the twelfth of the series, is to be followed by the thirteenth Paper by J. T. MacKenzie, which will be presented at the July, 1927, meeting of the Institute of British Foundrymen. Professor John H. Andrews, the author of this Paper, is Doctor of Science and Professor of Metallurgy of the Royal Technical College, Glasgow, Scotland. Dr. Andrews' work on the growth of grey iron is especially notable.

† Professor of Metallurgy, Royal Technical College.

[1] Okochi and Sato, "Journal College of Engineering," Univ. of Tokio, 1920, Vol. X, No. 3.

[2] Outerbridge, "Journal Franklin Inst.," 1904, Vol. 157.

[3] Carpenter and Rugan, "Journal Iron and Steel Inst.," 1909, No. 2, and 1911, No. 2.

[4] Kikuta, "Sci. Reports," Vol. 11, No. 1, 1922.

[5] Andrew and Hyman, "Journal Iron and Steel Inst.," 1924, No. 1.

[6] Pearson, Carnegie Memoirs of Iron and Steel Inst., 1926.

[7] Andrew and Higgins, "Journal Iron and Steel Inst.," 1925, No. 2.

**Oxidation of Iron Preceded by Oxidation of Graphite.**

That oxidation of the iron preceded oxidation of graphite was pointed out by Andrew and Hyman, who found that in the first rapid period of growth the carbon content fell very little, when, however, the second and less rapid growth stage was reached the graphite became rapidly oxidised as the heatings continued. Further, during the initial stages of graphitic oxidation a decrease in weight of the specimens took place, which is further confirmation of this view.

The methods employed by different workers may be classified into two categories, namely, the method of heating and cooling the irons in a furnace and measuring the increase in length and diameter after each successive treatment, and, secondly, that of successively heating and cooling the specimens in a dilatometer and measuring their increase in length through the temperature range. As an example of the first method Fig. 1 is a comparison between the determinations of Carpenter, Pearson and Andrew and Hyman, the irons selected for this purpose being as follows:—

| | T.C. | Si. | Mn. |
|---|---|---|---|
| Carpenter (*a*) ..... | 3.98 | 1.79 | 0.23 |
| Pearson (*b*) ..... | 3.77 | 1.55 | 0.87 |
| Andrew and Hyman (*c*) | 3.33 | 1.31 | 0.58 |

An interesting feature with respect to the three curves is the extraordinary similarity between the curve of Carpenter and that of Andrew and Hyman. Both of these curves show the beginning of the second period of growth between the tenth and fifteenth heat, the amount of growth up to this stage being similar in both examples. The only difference with respect to the two curves is that the curve of Andrew and Hyman shows the growth to take place continuously, whereas in the example from Carpenter growth practically ceases after thirty heats. This difference can be easily accounted for by the fact that the specimen of Andrew and Hyman became badly oxidised on the surface after thirty heats, thus increasing the superficial volume.

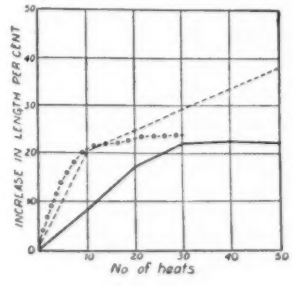


FIG. 1.

The difference in character between the two curves just considered and that of Pearson is marked. In the example taken from Pearson the primary growth period continues to thirty heats.

The peculiar fuzziness of the graphite flakes during the period of growth, particularly in the earlier stages, has been commented upon by many, and has usually been considered to have been due to admixture of oxide particles with the graphite. This feature, along with the fact that oxidation of the iron precedes that of the carbon, merits consideration, and it might be interesting to examine some possible reactions to account for the phenomena.

According to Eastman,[8] at temperatures between 0 deg. C. and about 600 deg. C. the reaction $2CO = C + CO_2$ will proceed from left to right. At temperatures above 600 deg. C. according to the ratio $\frac{CO_2}{CO}$ the reaction may proceed from right to left.

Further, below 600 deg. C. with a certain $CO_2 - CO$ ratio the reaction $3Fe + 4CO = Fe_3O_4 + C$ will also proceed from left to right, this reaction likewise being reversible, depending upon temperature and $CO_2$ to CO ratio.

It is quite possible that at low temperatures oxygen of the air combines with the carbon to form $CO_2$, and that this is immediately reacted upon by the iron on raising the temperature with the formation of magnetic oxide and carbon monoxide according to the equation

$$3Fe + 4CO_2 = Fe_3O_4 + 4CO.$$

On lowering the temperature again, the reaction $3Fe + 4CO = Fe_3O_4 + C$ might take place, giving rise to the fuzzy carbon already referred to. According to this suggestion a certain amount of the graphite consumed by the air would be redeposited as free carbon on cooling, while $Fe_3O_4$ would at the same time continue to form. Further, the reaction $2CO = C + CO_2$ might easily take place at the lower temperatures in presence of the catalyst iron and iron oxide.

That the formation of $Fe_3O_4$ along with a certain deposition of carbon does take place, and that this reaction is moderately rapid, is evidenced by the curves of Andrew and Higgins, which show an extraordinary and sudden expansion of the system beginning at a temperature of 600 deg. C. after a certain number of heats. A hypothetical figure has been drawn (Fig. 2) which indicates the general form of the curves for a cast iron containing about 4.0 to 4.5 per cent. of carbon and 1.5 per cent. of silicon. The curves drawn in this figure represent generally the type of curve obtained in the series of irons with varying manganese, the only difference between the different manganese contents being not in form but with respect to the position of the curve in the order of number of heats. For instance, with the high manganese series Type III persisted for several heats, but was eventually followed by curves of the type of IV and the following letters. A peculiar feature noted was that the heat preceding that which gave the large expansion on cooling invariably showed an excessively large coefficient of expansion during heating. Indeed, the variation in the coefficient of expansion during the different heatings was a noticeable feature of this work. This in itself supports the contention of Kikuta, who would appear to assume that the growth is largely brought about by abnormal expansions and contractions undergone by the different micro constituents. The author would, however, further suggest that the large expansion following upon a marked and sudden expansion on the previous cooling may be due to the newly-formed material such as $Fe_3O_4$, and possibly, in the earlier stages, deposited carbon, not being able to occupy their normal volume at the time of their formation. Upon heating up they are enabled to expand and so occupy their normal spacings.

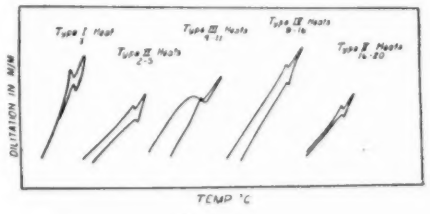


FIG. 2.

The contraction sometimes met with at later heats would seem to be due to the $Fe_3O_4$ segregating and occupying blowholes and the spaces left by the graphite. The results of Pearson, which show an increased growth in an atmosphere of $CO_2$ as compared with air, give further support to this contention. Up to the present it has been assumed that normal types of cast iron were being dealt with. Of the special irons Carpenter has shown that high manganese in the absence of high silicon considerably reduces the rate of growth. Andrew and Higgins found that, provided the silicon content was about 1.5 per cent., little difference was observed with a manganese content varying between 2.0 and 5.5 per cent. Indeed, manganese seemed to accelerate rather than reduce growth. A peculiar feature in the manganese irons was the sudden breakdown in patches of the manganese-iron carbide. Micro examination showed that in the same specimen there often occurred patches of manganese-iron-carbide perfectly intact, while other patches had

[8] Eastman, "Journal Amer. Chem. Soc.," 1922.

completely broken down into free carbon. When once the decomposition of the manganese carbide had been brought about, it was only to be expected that, manganese being a highly oxidisible element, growth would be accentuated, and this was a fact. The free manganese being in the nature of a decomposition product would be in an extremely fine state of division and most readily oxidised by the air. Phosphorus presents a more difficult problem, and in summing up their work Andrew and Higgins were unable to make any definite statement with respect to the action of phosphorus.

Certain facts are, however, borne out by their experiments, namely, that a phosphide-iron-carbon eutectic is more stable than the pure iron carbide eutectoid, it would seem as if the phosphorus prevented the carbide of iron from decomposing. That this is so is evidenced by the fact that with the lowest phosphorus iron selected for their experiments, which had a phosphorus content of 1.30, practically the whole of the combined carbon was graphitised during the first cooling. As the phosphorus content increased, however, the process of graphitisation became slower. Another peculiar feature with respect to the higher phosphorus irons containing phosphorus from 2 to 4 per cent. was the marked contraction which took place on soaking at 900 deg. C. This was found to be due to the phosphide of iron liquating, and filling in the free spaces left by the graphite and those due to blowholes. Phosphorus, although uncertain in its effects, would seem to slightly increase the growth of iron.

Viewing the effect of the different elements upon the growth of iron, it would seem that elements which accelerated the graphitisation of the carbide such as silicon, aluminium and nickel increased growth, while elements such as manganese in the absence of elements of the first class, chromium, and other carbide-forming elements, also carbide stabilisers such as sulphur, would tend to decrease the growth. In other words, it would seem that it is only those elements which will give an unmachinable white iron which will retard to any extent the rate or magnitude of growth.

### Growth on Heating to Below 700 deg. C.

With respect to what may be described as low-temperature growth, the recent work of Higgins* brings to light many interesting facts. His low-temperature dilation curves give one the impression that low-temperature growth is due to the same phenomena as is high-temperature growth. His curves show a marked variation in the coefficient of expansion, which corresponds with the same feature in the high-temperature curves of Andrew and Higgins. His photo-micrographs show conclusively that formation of oxide of iron takes place readily, and that it is this reaction which is chiefly instrumental in bringing about the expansion. That the greater part of the carbon remains unattacked is evident also from his photos, although a certain fuzziness along the graphite flakes points to the formation of $Fe_3O_4$ along with a deposition of carbon.

It must not be overlooked that the deposited carbon is the result of a high-temperature reaction in which the graphite becomes oxidised, followed by a further reaction in which the CO or $CO_2$ again breaks down with deposition of carbon. The term high-temperature reaction is, of course, used relatively.

### Low- and High-Temperature Growth in General.

When the extraordinary heterogeneity of cast iron is taken into account, it becomes more remarkable to find such an extraordinary agreement between the results of Carpenter and Andrew and Hyman. In considering the factors involved in the growth, the particular configuration of the micro constituents must not be lost sight of. If, as in most cases, the type of section experimented with is in the form of a round bar, then the angle which the graphite flakes make to the longitudinal direction here of the bar must not be overlooked. Supposing, for instance, that in one case the graphite flakes which have become filled with oxide material lie in a direction parallel to the length of the bar under test, and in another case that they all lie at right angles to the length. It is obvious that the expansion along the length and across the diameter will be different in the two cases, and whereas the total increase in volume would be the same in both cases, the measurement in the increment in diameter of the bar cannot be as accurate as one taken along the length. This is in no way due to inaccuracies in actual measurement but rather to the fact that surface oxidation will have a greater effect upon the diameter than upon the length. The particular arrangement and size of the micro constituents will, therefore, have an appreciable effect not only upon the magnitude but upon the rate of growth, and also upon the coefficient of expansion over the whole range of temperature employed.

It would seem quite evident that, as has previously been stated, no machinable iron can resist the powers that bring about its growth. The rate of growth may be retarded by the addition of certain elements, but provided any iron is continuously heated and cooled for a very large number of heats, growth will invariably take place. Even in the chromium irons experimented upon by Andrew and Hyman, the temper carbon which formed by decomposition of the chromium carbide gradually became replaced by oxide material, showing that growth was purely a question of degree and of time.

It would seem that the only way of preventing growth would be to deposit on the surface of the iron some metal or other substance which is impermeable to gases, thus preventing access of air to the graphite flakes and therefore to the interior of the casting. Even then graphitisation of the combined carbon would still bring about a certain amount of permanent expansion.

### Conclusions.

From the work of others and his own the author has come to the following conclusions respecting the underlying causes of growth in cast irons. Growth is brought about as follows:—

(1) By graphitisation of combined carbon.

(2) By percolation of air through the graphite flakes and channels in the iron bringing about oxidation of the ferrite, with the formation of $Fe_3O_4$, and probably finely deposited carbon.

(3) A certain amount of contraction will eventually result from oxidation of the graphite and deposited carbon, but this may be balanced by further and continuous oxidation of the ferrite.

(4) Every time the iron is heated and cooled its structure will be changed due to the previous treatment, with the result that the coefficient of expansion will have altered. Further, the expansion of oxide material and direction in which this lies with respect to the length of the section employed will bring about a difference in total expansion at every heat, and will result in a breaking apart of the particles at certain areas, which in itself will cause growth.

(5) The author does not think that occluded gases, or rather their physical effect, can bring about any permanent expansion. Oxidised gases in reacting with the iron or the carbon will, of course, have the same effect as similar gases added externally.

* Higgins, Carnegie Memoirs of Iron and Steel Inst., 1926.

## Personal.

MR. J. STONE, assistant works and foundry manager to the Calcutta works of Marshall & Sons, Limited, of Gainsborough, is at present on leave in England, and his many friends in the industry can reach him by addressing correspondence, c/o the Editor of the FOUNDRY TRADE JOURNAL, 49, Wellington Street, London, W.C.2.

MR. F. C. FAIRHOLME and Mr. Mark Firth have resigned from the board of the Chesterfield Tube Company, Limited. These gentlemen were invited to join the board for the purpose of collaborating over problems connected with the manufacture of tubes from corrosion-resisting steels, the firm they represented (Thos. Firth & Sons, Limited) being the leading makers of such steels. The purpose has been achieved, and it has now been mutually agreed that future business can be carried on with greater benefit on independent lines.

# Influence of Iron Castings on Progressive Engineering.

By "Progrès."

### Cupola Practice Generally Poor.

During the last two or three years the leading technical journals of Great Britain, the Continent and U.S.A. have paid special attention to the necessity for improving the quality of iron castings, both in regard to their metallurgical and physical properties. It is almost safe to say that iron foundry practice throughout the whole world has made little, if any, advance metallurgically during the last 50 years.

Iron castings, both light and heavy, are still made from variable and, in many cases, questionable qualities and quantities of pig-iron and scrap charged more or less indiscriminately into a cupola, which eventually melts whatever is charged into it reasonably economically, from a fuel-consumption point of view. The majority of such cupolas are run and controlled by uneducated cupola hands under the supervision of a foundry foreman, who very seldom has any metallurgical knowledge, and who judges both pig-iron and scrap more by vision than by analysis, and who is generally quite willing to use whatever is supplied to him by the works' purchasing department.

Only the largest engineering works who have foundries at the present time employ a foundry chemist who can, and does, analyse, select and control to some extent the quality of the metal charged into the cupola. Such chemists, however, seldom have much authority outside their laboratories, and are not allowed to control the working of the cupola itself.

### Chemical Control Essential.

It is, however, obvious that the molten metal which is poured into the moulds is the important factor, and no matter what care is exercised in the choice of the charged metal, the analysis of the molten metal can be materially altered and, in fact, made entirely unsuitable for the purposes required. The percentage of sulphur and total carbons particularly can be entirely altered in the cupola by the percentage of coke, lime and, most important of all, temperature.

There are ordinary cupolas when blown by uncontrolled Roots blowers which have used up to 18 per cent. of charge coke, and even with this excessive amount of fuel the molten metal has not exceeded 1,300 to 1,350 deg. C. when poured. No cupola under proper control with a suitable fan or blower from which the correct volume of air is passed into the cupola needs more than 10 per cent. of coke for molten metal at a temperature of 1,350 deg. C., or more than 12 per cent. of coke for molten metal at 1,450 deg. C. The only reason why larger quantities of coke are used at any cupola is because such excess coke is necessary to combust the great excess of air which is invariably blown in through the tuyères. Endless articles and papers have been printed and read upon the correct design of cupolas, and a great mystery has been allowed to grow up in connection therewith, all of which is so much camouflage. The cupola is a circular steel tube lined with refractory material with four or more inlet holes near the bottom through which air is blown to produce combustion and retain a sufficient temperature to melt the iron and flux. Common sense dictates that the total height of the cupola depends only upon its position to surrounding buildings, but the height at the same time controls to some extent by virtue of draught the working of the cupola and the subsequent composition and temperature of the waste gases.

### Physical Necessities.

The most important feature of its correct design is the height or depth of the charge from the tuyère inlets to the charging door. This dimension, if perfect combustion and hot metal is required, should not be less than 3½ times the interior diameter of the cupola at the tuyères. In good cupola practice 202 lbs. of coke and 540 cub. ft. of air per minute at atmospheric temperature are required to melt one ton of iron to liquid state, and in all cases a Pitot-type tube should be fixed to control the volume, and it should be possible to take gas samples from different points up the shaft of the cupola so as to enable the air to be controlled according to the CO and $CO_2$ contents as shown.

In all cases the tuyères should be so designed as to allow of regulation according to the density of the charge, which varies considerably at different points in the cupola dependent upon the size of the coke, scrap and pig charged. The air pipes which supply the air to the tuyères should preferably never form a part of the cupola body and should never be rectangular, as gases will never flow as evenly round a rectangular tube as through a cylindrical section. Also, it is almost impossible with built-in rectangular air tubes to regulate or control the volume of air passing through each tuyère, owing to the tendency of the tuyères to be blocked by slag and other matter which necessitates constant and sometimes dangerous poking.

### Air Pressure.

There is no rule, either necessary or possible, relating to the pressure of the air, as this depends entirely upon the state and design of the cupola and the nature of the charge. In all cases there should be sufficient air pressure at the tuyères, say, 10 in. to 12 in. on water gauge, to allow the air to pass through the charge to the centre, circulate freely, and efficiently overcome the resistance in and up the shaft. This resistance varies with the charge, and for this reason the blower should be regulatable, so that the pressure, but not the volume, can be increased. It is believed there is an automatic device called a "Multiplicator" which can be fixed to blowers which indicates any variation in resistance, which device it is advisable to attach in all cases if a regular supply of metal of constant quality is desired.

### Modern Variations in Cupola Practice.

There are on the market many new devices for improving the efficiency of the cupola, most of which are entirely unnecessary if ordinary common-sense precautions are taken. None of them will make a badly designed or ignorantly controlled cupola good.

Attempts have been made in the past to regenerate the combustion air, notably the Schürmann system, but whilst it was possible to improve by reducing the previous waste of charge coke by this means, it was quite obvious that the economy so gained was caused more by the corrected control of the volume of air than by any calorific gain from the regenerated air, as to get the heat into the regenerators one had to rob the cupola of hot, uncompletely combusted gases at the tuyère level. No doubt also some improvement in combustion and consequently ultimate higher metal temperature was also gained, and it is quite certain that at some future time a design of regenerator or recuperator will be invented whereby the whole of the waste gases will, if they are of sufficiently high temperature, be taken from the cupola above the top of the charge. Such an arrangement would, however, necessitate a closed charging bell similar to the blast furnace and, the author understands, experimental work in this direction is already being carried on to a very considerable extent on the Continent, principally in Germany.

### Regenerative Cupola Practice.

To show the value of regenerated air and its influence upon fuel economy, there follows a table which was the result of careful practical research

into the use of hot air at various temperatures blown into a cupola:—

| | | | | | |
|---|---|---|---|---|---|
| 1. Average temperature of preheated blast .. | 0°C. | 200°C. | 400°C. | 600°C. | 800°C. |
| 2. Sensible heat content of blast per lb. of coke in B.Th.Us. .. | — | 1,050 | 2,400 | 3,150 | 4,200 |
| 3. Total heat input per lb. of coke in B.Th.Us. .. | 13,000 | 14,050 | 15,000 | 16,150 | 17,200 |
| 4. Theoretical amount of fuel required in percentage.. .. | 4.15 | 3.85 | 3.6 | 3.35 | 3.15 |
| 5. Fuel actually required in practice in percentage.. .. | 8.0 | 7.4 | 6.88 | 6.45 | 6.05 |

By these figures it will be seen that the calorific efficiency even of a well-controlled cupola leaves much room for improvement, and the best results will only be obtained when the utilisation of the majority of the heat of combustion is transferred to the charge and the waste gases leave the shaft at the lowest possible temperature.

### Cupola Receivers.

Before leaving the cupola the question of a forehearth or receiver should be referred to. In the writer's opinion, all cupolas of any size should have some type of receiver, as it is only by this means that a consistently regular quality of metal can be tapped. It is quite certain that unless the selected pig-iron and scrap are charged into the cupola in mixed packets at the same time, one will get from the cupola molten metal consisting of molten pig or molten scrap exactly as it is charged, but with a receiver one obtains a mixture of all the charge and also metal which contains less sulphur, as during the period the metal is collecting and resting in the receiver, absorption is taking place constantly. It is quite easy to retain the temperature in the receiver, if it is to be held there for any time, by putting in an auxiliary oil-burner of the Hurst type. It is also worth while considering one of the various devices now on the market for jogging the receiver, which is particularly valuable if it is desired to add any of the desulphurising media now on the market to reduce the sulphur, or to add molten alloys.

### Tapping and Botting.

Having now taken reasonable precautions to obtain good-quality hot metal at the tapping spout, it must now be removed, and the same crude and dangerous method of pricking a hole through a refractory bott is still found to be prevailing. Only one man at each cupola is ever allowed to do this, and thus foundries have built up a fictitious value to this simple action. It is known to the writer that an attempt was made a year or two ago to introduce into England a mechanical tapping and botting-in device. This device is being very largely used in Germany and with consistent success, not only on cupolas, but on air and other types of melting furnaces where tapping holes up to 3-in. diameter are required. Every effort to work this device successfully in Great Britain met with failure not from any fault in the device, but entirely owing to the fact that the cupola men did not want it and would never work it correctly, either in regard to the correct mixture and consistency of the botting material, or in regard to the correct amount of force required when inserting the bott. In other words, the special men did not want this long-time specialised operation to be brought within the power of any untrained workmen, and so the devices were, it is thought, in every case discarded.

### Ladle Practice.

Assuming the metal is now ready for tapping from a cupola without forehearth, the tapping operation is proceeded with and the metal is run into the ladle. During the filling of the ladle, according to its size, it often occurs that the tapping hole is re-botted because too much slag is coming down the spout. This is caused either through the inferior slagging of the cupola or through a badly designed or shallow metal bed holding too little molten metal at the fixed tapping level. Slagging in a good cupola should be continuous, and the slag should always be run into a slag pan or ladle, and should never be allowed to fall on the foundry floor, where it forms a dangerous inconvenience and often a trouble to remove.

Meantime, the metal already in the ladle is getting cold. When the ladle is eventually full it is taken to such part of the foundry far or near to be poured into the moulds or into small shanks, but nearly always too much delay occurs before the metal is finally poured into the moulds. In the best foundries the slag which passes into the ladles is removed at the cupola, but in many others it is carried to the mould, and there very crude and often inadequate precautions are taken to prevent some of it being poured into the mould, in which case the chances of a perfect casting are small, as such slag invariably seems to solidify at the most important part of the casting.

The average pouring ladle used in foundries leaves a lot to be desired, and the writer has on many occasions seen one, two and even three men using great force to pour the metal out of small ladles from 1 ton to 5 tons holding capacity. Metal poured into moulds from such ladles cannot produce good castings owing to the irregularity of the flow, the dangerous splashing, and often the wasteful overpouring. Good, even pouring ladles can be obtained, and in view of the extreme importance of this operation and its bearing upon the resultant casting, all ironfounders are strongly recommended by the author to investigate very carefully this detail, both in regard to the slag and the even and easy pouring.

### Avoiding Dirty Castings.

Having now arrived at the passing of the molten iron into the moulds, it is well to consider what happens at this stage. In most dry-sand foundries moulds and cores for good castings have been stoved and dried more or less efficiently, and the moulds have presumably been vented to allow the gases to escape without excessive bubbling or internal explosion. In complicated castings, especially of large size, the metal runs down one or more runners connected by an ingate to the mould. The object of this multiplication of runners is to allow the metal to be equally distributed throughout the mould, so as to fill the mould as speedily as possible and prevent irregular contraction during cooling.

In a few British foundries and in many of the leading foundries on the Continent, this multiplication of runners has been extended, and the Nutarelli filter has been largely adopted with very excellent results, especially in the manufacture of motor-car cylinders, liners, drums, and long axle housings and the like. The recognised advantage of such filters is the exclusion of slag and other foreign matter and the entire elimination of air bubbles. The result is that by such means one invariably obtains homogeneous casting. The adoption of such a method would produce better castings with a reduction in wasters at very little additional cost.

### Draws in Castings.

In every case, no matter at what temperature the molten metal is poured into the moulds, the cold walls of the sand mould must inevitably cause the thinner sections of any casting to cool more speedily than the thicker sections with the natural and generally accepted result that there is always a draw and a consequent tendency to porosity at the junctions of thin and thick sections which results in weakness and often causes the castings to crack during cooling contraction. This trouble is invariably overcome in castings which are not subjected to interior pressure by making these differences as slight as possible, and by generally increasing thicknesses and thus adding to the weight. This trouble can to a certain extent be overcome by pouring metal of high temperature so that the period of cooling is delayed by warming the walls of the mould, but even so the fault is always appearing, and with increasing pressures, higher temperatures and the necessity for reduced

weight in the construction of modern machinery very few foundries to-day can meet the demands placed before them.

### Solving Fundamental Difficulties.

First, who is to blame that so little scientific and practical progress has been made in the production of cast iron? The author would first blame the British Engineering Standards Committee; secondly, the consulting engineer, whose demands are always increasing; thirdly, the designers of engines and machinery who have accepted cast iron of low tensile and other physical qualities as a basis for their calculations; and, lastly, the foundry owners who have more or less deliberately refused to spend money upon the metallurgical research necessary to keep their most important industry in line with the great progress which has been and is continuously being made in the production of plain and alloy steels.

In almost every class of machinery except perhaps cranes, bridges, locomotives and rolling stock, cast iron forms the greater part, and certainly has the greatest weight. So bad is the position that less than two years ago the Diesel Engine Manufacturers' Association met in Glasgow to discuss the problem, and the final conclusion arrived at was that cast iron as such and as known to them was no longer a suitable metal to be used in the construction of Diesel engines or even high-pressure turbines. It is well known to all engineers that the standard of cast iron quality set by the British Engineering Standards Committee calls for a maximum of 14 tons tensile. Why not 16, 18, 20 or even 25 tons, all of which are possible and practical?

It is quite true that castings made to-day in which sections vary from, say, 1 in. thick to 3 in. or 4 in. thick, will vary in tensile from 14 tons at the thin sections down to 7 tons in the thicker sections. It is also known that in large castings, such as heavy marine cylinders, bedplates, and the like, weighing many tons, a very large excess of metal is left on for machining, and this is done with the object of getting a sound casting. Unfortunately, the results do not always justify this method, except in so far as the foundry get paid on the weight and, incidentally, this may account for their lack of desire to improve the quality and at the same time reduce the weight.

It is incontestible that if a section of any iron casting is broken the grain and structure of the iron is closer, and therefore stronger on the outside, and grows more open and therefore weaker towards the centre. This fact is visible to the eye, and, microscopically, it is only too evident.

Many of our leading engineering works with foundries have during the last few years strenuously endeavoured to improve their iron castings, and have employed chemists and fitted up laboratories in which a great deal of research work has been carried out with comparative success. Indeed, a Cast Iron Research Association has been formed, and is doing good work, but even this Association is only patronised by a small percentage of the foundry industry, many of whom still appear to think that membership of the Association alone is all that needs to be done, and give little attention and less encouragement to the research work so ably carried out by the experts of the Association.

The author believes the answer to the problem of improving iron castings is to be found in the practical results now available, due to the lengthy, expensive and successful practical research work which has been done on the Continent during the last 10 years.

It is a little over two years ago that the writer first had his attention drawn to the "Diefenthaler" process for the production of pearlitic cast iron. Upon investigation it appeared that Diefenthaler had been the foundry manager of the firm of Messrs. Heinrich Lanz, of Mannheim, and that he, like others, had been faced with the necessity of producing stronger, lighter and more consistently reliable castings. His first serious series of experiments consisted of gradually increasing the temperature of his molten metal whereby he obtained greater reliability and consistency, but did not increase the tensile or other physical properties, nor did he overcome the difficulty of draws and porosity. His next series were in the direction of first charging the cupola with carefully selected pig-iron and scrap; secondly, melting same to high temperature; and, thirdly, of delaying the cooling by placing the moulds after casting into a hot furnace for cooling down at various temperatures until he arrived at some reliable degree of improvement.

The cost in time and labour and the limitations of his furnaces, and the lack of sufficiently heavy and speedy handling plant quickly proved to him that this method, although good, was impracticable, and he therefore commenced a third series of experiments. Still using selected metal for charging the cupola, which metal he melted to 1,450 deg. C., he commenced pre-heating his moulds, and after lengthy, arduous and expensive experimental work, he at last reduced his process to a practical certainty, and obtained usable curves of mixtures and mould temperatures with variations according to casting thicknesses which finally enabled him to apply for and obtain his Master Patent in Germany. The fundamental basis of these patents is the selection of metal with low total carbon and silicon content combined with the heating of the moulds.

Whilst Diefanthaler and his associates were carrying on their research, other German foundry metallurgists were also doing similar work, but in an entirely different direction, the most prominent of these being Mr. Karl Emmel, of Thyssen & Company, Mulheim, Germany, who, being large manufacturers of high power gas engines and steam turbines, were also demanding higher qualities of cast iron.

Mr. Emmel's investigations, although they obtained excellent results, consisted mainly in, first, a practical improvement in cupola practice; and second, in a metal charge consisting of gradually increasing percentages of scrap steel to the elimination of the more expensive pig-irons. It is only right to say that Mr. Emmel's research work has successfully enabled him to produce iron castings of extraordinary physical and structural quality, without apparently in any way infringing the Diefenthaler-Lanz patents.

The Emmel process, for which British patents have recently been obtained, is to-day enabling a considerable number of British and Continental foundries to produce iron castings from cupola charges containing up to 90 per cent. of steel scrap, which gives a tensile strength up to 25 tons, and which even under the microscope show little or no variation in the structure from outside to centre, and practically no physical variation throughout the different sections. These castings are not all pearlitic like the Lanz-Perlit castings, but are both pearlitic and ferritic in structure, and give great resistance to internal pressure even with thin wall castings.

These two processes have been very fully discussed, not only by the technical Press, but they have formed the text for many articles and Papers read before technical institutions by many of our leading metallurgists.

For many years the requisite ideal quality of cast iron has been put forward by our leading scientists, such as Dr. Stead, Professor H. C. H. Carpenter, Professor Turner and our leading foundry chemists, Mr. J. W. Donaldson, of Greenock, Mr. C. E. Pearson, Mr. H. J. Young, Mr. J. E. Hirst, and many others who have carried out most comprehensive research work into the qualities and claims of irons made by both processes, and in no case have any of the claims been refuted. Also Dr. Piwowarsky and Dr. Bauer, of Germany, have also written at length on the sulphur qualities of Perlit and Emmel irons.

In February last an important Paper by Mr. J. W. Donaldson, describing lengthy experiments dealing with the growth of cast iron at high temperatures, was read before the Institute of British Foundrymen (Lancashire Branch), reports of which appeared in THE FOUNDRY TRADE JOURNAL on February 17 and 24, and the conclusions proved that Perlit iron as made by the Lanz process was vastly superior to any other qualities of cast irons.

An important treatise on the "Growth of Commercial Grey Cast Iron," written by Mr. C. E. Pearson, B.Met., of Armstrong College, Newcastle-on-Tyne, and which appears in the Carnegie Scholarship "Memoirs" of the Iron and Steel

Institute, Volume XV for 1926, gives conclusive evidence of the superiority of Lanz-Perlit iron to resist growth at temperatures up to 1,000 deg. C.

Professor H. C. H. Carpenter, when delivering the annual James Forrest Lecture before the Institute of Civil Engineers recently, gives only one example of real advance in the foundry production, and this he considered to be the production of perlitic cast iron under the Diefenthaler process.

Evidence proves, therefore, that British foundries have at their disposal two excellent and well-proved processes, the Lanz-Perlit process and the Thyssen-Emmel process, neither of which overlap or infringe each other's claims, but both of which produce castings infinitely superior to anything obtained by any other known method. The Lanz-Perlit process has probably certain limitations owing to the advisability of using moulds heated to temperatures up to 500 deg. C. for obtaining complicated special castings with low silicon content, high in tensile, with great resistance to impact and abrasion. Many foundries have only a limited stove capacity, and might find difficulty in adopting this process without some additional expenditure. Even, however, with this process it is claimed that the cost of production is only from 5 to 10 per cent. higher than castings of cylinder iron quality, the extra cost being due to the heating and handling of the moulds and cores to and from the stoves. These costs are partially written off by the fact that cheaper qualities of pig-iron can be used for obtaining suitable Perlit mixture.

The Emmel process does not, however, call for the heating of the moulds, and also uses a higher percentage of scrap steel which very considerably reduces the cost of the charge, and, consequently, of general production. It is also claimed by Emmel that castings made by his process can be malleabilised in less than half the time now occupied. If this claim can be proved then this process should be of real interest to every malleable iron foundry in this country.

In view of the above facts, surely the author is justified in asking for some strong reason why these processes have not been adopted by all the leading foundries in this country. I am informed that there are in Great Britain only seven licensees of the Lanz process and three licensees of the Emmel process, whereas we have about 3,000 iron foundries in Great Britain. It is, however, interesting to note that the firms who have purchased licences are those who have the largest research laboratories and who had already made considerable progress in the improvement of their iron castings.

The author has been informed that many foundries have hesitated to take up either process for fear of litigation owing to the possibility of either process infringing the other, but this fear has no real justification. It also appears probable that in the near future British foundries will be able to purchase a licence which will include both processes on attractive terms.

It can now be seen that there can be no excuse for further allowing inferior, out-of-date iron castings to interfere with engineering developments, as by adopting either or both of the above processes low silicon iron castings with a minimum heat growth can be produced suitable for Diesel engines, steam turbines, gas engines, locomotives, boiler fittings, superheaters and all classes of machinery which are brought into contact with modern high temperatures. Castings dense in structure, non-porous and without draws can be produced for use in the manufacture of ammonia and refrigerating machinery, chemical and brewery plant and for all castings handling by-product recovery, coke ovens, gas plants and the like, castings high in tensile and other physical properties greatly resistant to all strains either from impact, abrasion or internal or external pressure, such as tube tubbings, engine foundation beds, heavy tools, etc. All these castings can be reduced in weight by from 10 to 40 per cent. without decreasing the ultimate strength, and thus for the first time in the history of iron castings the designers of machinery will be able to calculate their weights and strengths with a certainty that the desired tensile will appear equally throughout all sections of every casting.

The remedy, therefore, is undoubtedly in the hands of the advisory and consulting engineers to the Government Departments, railways, shipping companies, Corporations and other public bodies whose business it is to obtain the highest quality of plant available as whatever they specify the engineering works and foundries will produce. It is up to Great Britain again to be the pioneers of engineering progress and to do everything in their power to retain and, where lost, to recover the position they have held since engineering first became the most important factor in the development of world progress.

## Book Review.

**The Metallurgist's Manual**, by T. G. Bamford and H. Harris. Published by Messrs. Chapman and Hall, of 11, Henrietta Street, Covent Garden, London, W.C.2. Price 15s. net.

Professor Turner, who has contributed a foreword to this volume, points out that whilst both the authors are lecturers on the staff of the University of Birmingham, they both have held important metallurgical positions in many parts of the world. The reviewer remembers when he was in charge of a steel works laboratory how he felt the need of such a book as this. Whilst he, at that time, felt convinced he was well equipped for the prosecution of determinations of the elements ever to be found in ferrous alloys, he was somewhat lost when occasionally called upon to deal with non-ferrous alloys and certain minerals. Particularly does he remember searching for a reliable method for estimating the quantity of $CaF_2$ in fluorspar. At this period, the then largest merchant refused to disclose the method employed in his laboratory. Thus we were a little disappointed to find no mention of this important flux of which some thousands of tons are absorbed annually in the metallurgical industries.

Apart from this it will be seen from a recital of the contents that the book is very comprehensive in character and can be consulted with confidence by metallurgists when dealing with a job not tackled under their normal routine. The book is divided into eight principal sections. They are:—Assaying; analysis; fuels and refractories; smelting; pyrometry; metallography; summary of the manufacture of non-ferrous castings; and tables.

These absorb some 250 well illustrated pages, whilst the book is particularly well indexed.

We do not care for the table bearing the caption, Typical Analyses I, which has reference to steel. For instance, we know of no classification in British industrial circles which comes under the heading of "Ingot Steel," and suspect it to be a bad translation from the German, which is usually covered by "dead mild steel," or perhaps it may refer to "Armco" type iron. For high-speed the typical analysis given is C, 0.4 to 1.2; Si, 0.1 to 0.2; Mn, 0.4 to 0.5; S, 0.05; P, 0.04; Cr, 3.0 to 4.0; V, 0.25 to 0.5; and W, 13.0 to 15.0 per cent. Primarily, the carbon range is far too wide, and the tungsten range far too restricted, whilst the vanadium range should read 0.0 to 0.5. Further, the inclusion of semi-steel under the caption "Steel" helps to perpetrate the crime of passing off what used to be the best of grey cast irons as a ductile material. There are several other objections one could usefully raise with reference to this table, but we prefer to suggest a complete revision, giving in the case of every element a practical range of which the mean may be designated typical.

As stated at the beginning of this review, the book is generally thoroughly reliable, and should be appreciated by metallurgists throughout the world. We hope it will run into many editions and that users will acquaint the authors with what they consider could be usefully incorporated, as it has a definite place in the library of every inorganic laboratory.

AN EXPLOSION damaged a blast-furnace at the Oldside Ironworks, near Workington, on Thursday, June 9. The base of the furnace was damaged, and a quantity of iron lost, but operations were resumed without much delay.

# Runners and Risers.

### Yorkshire Foundrymen Discuss Important Phase of Foundry Work.

Before the West Riding of Yorkshire Branch of the Institute of British Foundrymen, Mr. J. Butterworth, of Halifax, read a Paper on "Runners, Gates and Risers," which we printed in a recent issue. Mr. W. Parker presided. MR. J. G. ROBINSON (Halifax), in opening the discussion, said it was a Paper which raised a good many controversial points. He could not agree entirely with Mr. Butterworth's suggestion that for the plate pulley it was better to run from the bottom edge of the rim. If it was run from the outside and the metal rose up to the rim, when it reached the plate it had to fill the plate and the boss after, and in most cases, in his (Mr. Robinson's) opinion, it would leave a dirty place. Personally, he regarded it as better to run down the boss. To eliminate gases, the vents should be suitable for them to evacuate without a loss of pressure. Mr. Butterworth had declared that he saw little use for dummy risers, but in his (Mr. Robinson's) experience he had known cases in which they were essential, but not always for feeding purposes. In malleable iron and steel work it was often necessary to put on dummy risers because one could not get risers to feed from the outside. When gas—or it may be air in the mould—was heated up to the temperature of the metal it had to escape, and when it left the face of the mould, it reached the damp sand and lost in volume. The pressure of the air was reduced on account of the reduction in the temperature. In the matter of weighting the casting, Mr. Butterworth had mentioned three to one as being not sufficient in some cases. He (Mr. Robinson) hardly thought the question of weight entered into the matter at all. It all depended on the area of the surface of the casting and the head pressure.

MR. BUTTERWORTH, replying, said for plate pulleys it had always been the recognised system in his shop to run from the bottom, and whenever they did have occasion to run one from the top it generally resulted in scabbing. In regard to the three to one weight mentioned, in a jobbing shop the moulder would put three times the weight there was in the casting and it would hold it. He (Mr. Butterworth) thought in many cases that was insufficient.

MR. S. W. WISE said he thought nobody could lay down hard and fast lines for any particular casting or type of casting. He had been very interested in the comments of Mr. Robinson in regard to the weight required for holding the top part down, and agreed that weight *per se* had really very little to do with the matter. It was rather a question of head pressure. He agreed that risers were not much use in removing dirt, and if there was dirt in a mould it was likely to be found on the casting. When Mr. Butterworth referred to a tapered riser-stick it would be interesting to know exactly the amount of taper he meant. If one used a long yet small diameter riser one was only increasing the cooling surface. If one made a true cone and had a good volume of metal then it was useful, but the majority of risers on most jobs were not used for feeding purposes because they were chilled before they had a chance of feeding. One point on which he could not agree with Mr. Butterworth was in his preference for a pear-shaped stop, because there was a chance of the metal trickling down and forming a cushion. Such metal would set instantly. From this it was carried up not completely melted to parts of the casting where it was not wanted. This matter led one to think of the question of "shotting." There was a tendency on the part of many to confuse shotting on the outside of the casting with the shots found on the internal parts of the casting. Whilst the Paper contained much debatable matter because there was much controversy as to just how a casting should be run, there were, however, to-day certain general rules for the work which most of them were prepared to follow, and he believed the industry had departed from the old "hit and miss" methods.

MR. BUTTERWORTH, replying to Mr. Wise's comment on the pear-shaped plug, said the plug was used so that the metal was just dribbling down the side.

MR. F. BERRY (Halifax) said that on big melts it was his practice to cut a small gate under the plug for the metal to dribble in, and he had never had an accident. Sometimes with a big cast if the metal did not trickle slightly one would get an explosion. A drastic way in which this was sometimes to be seen was if two biggish jobs were being cast near to one another, one might cast one job and wait half an hour or so before doing the other, and when the second one was cast—especially if the coke bed was the same—in either of them one could get an explosion. Mr. Berry suggested that it was the metal that was lifting the top part, and that was where the question of the area entered when one calculated the amount of weight for holding down. Personally, he did not think gases did very much lifting. When one was casting a mould he thought that primarily it was practically all air that was in the mould, but when one had gases from a neighbouring mould, as in the instance he had mentioned previously, it gave a larger explosion. Mr. Berry agreed with Mr. Butterworth's views as to risers, they should always be of generous size, but there was not such a wide range of application as most people imagined. Metal should not be run so very hot, because if in the heavy part it was getting into the pasty condition it did not necessitate a riser.

MR. BUTTERWORTH, replying, maintained that it was the gases that lifted the top part. The gases accumulated in a mould more quickly than they escaped, and that being so they must press against the top part.

MR. BERRY insisted that the pressure was diminished by the vents.

MR. BUTTERWORTH asked as to where the whistling noise came from, whereupon Mr. Berry agreed the question was debatable.

MR. W. T. THORNTON (Bradford) said he would prefer to run a plate pulley down the boss, but if the plate were strong enough it sounded reasonable to run it on the plate. In large work he thought a combination of bottom and top running was satisfactory. The bottom runner filled the mould and then filling the top plugs it relieved the bottom lift. He did not think dummy risers were much use, because the casting remained hotter than the dummy riser. With regard to the matter of the weighting castings, an easy rule which could be calculated by any foundryman was that the area of the top part of the casting in square feet multiplied by the depth from the top of the runner to the bottom of the runner, in feet, divided by five, equalled the tons weight required to hold the top part down. In any case, one had to consider the velocity of the mould.

MR. J. J. WATSON (Huddersfield), referring to this question of pressure on the mould, suggested as a useful general rule that the area of the casting multiplied by the depth of the box gave square inches, and that multiplied by 0.26 lb. gave the pressure.

MR. L. FARRAR (Shipley) said one point mentioned by Mr. Butterworth was as to risers not necessarily being on the highest point. He once made a little casting in which there was a slight defect. It was a friction pulley, having a riser on the boss. He did this by instructions of the foreman. Personally, he had a general conviction that the heaviest part of the mould would feed itself, but the lighter parts needed feeding. It was the case in the instance he mentioned. He knew this was an idea with which some would not agree. An older man who took on the job put two risers on the pulley rim and fed it there and not on the boss at all, and he got a good casting. Another principle to which he (Mr. Farrar) held was that the riser should be practically a part of the casting.

MR. R. D. WELFORD (Bradford) said there was no doubt that a proper runner was the first step to a good casting, but he would have liked the author of the Paper to have told them something about the runner box. Moulders often did not think of the differences in size of the down-runner and the combined in-runners. A man may use an inch diameter runner for one job and the next day put in a 2-in. runner, failing to realise that

the diameter of the runners varied according to the square of the diameter. Personally, Mr. Welford said he did not see the necessity for the "trickling-in" method under plugs. A little trickling-in would ignite the gases just as much as if the whole plug were lifted, and he did not see any material difference between lifting the plug and trickling in some metal first. In regard to the pulley plate, he agreed with Mr. Robinson that there would be a dirty place on the outside of the rim unless the metal was very hot. On the question of the gases lifting the top part of the mould, that might happen if there was an explosion and the mould was very wet. The lift of a mould was done by hydrostatic pressure, and its natural effect upon metal pressing against the top part, the amount of which could be easily calculated. A cube 12 in. sq. on the top part had no greater lifting power than a square plate 1 in. thick, if the riser and the runner were the same height from the top of the mould. The gases had no effect on that lifting pressure. It was, in his view, a fallacy to put on risers with a view to catching dirt. If there was any dirt it would usually go somewhere other than in the riser. Sometimes risers were a real disadvantage, especially in moulds which had a large number of cores in them. If one fitted a riser in such case there was a tendency to find the metal coming up through the expansion of the forces. Mr. Welford said he could quite appreciate and understand the experience mentioned by Mr. Farrar. There was, he went on, quite a considerable difference between running a casting with hot metal and with cold metal; also the runner should be large enough to fill the mould reasonably quickly.

MR. H. SAYERS (Leeds) said the first rush of metal was usually that which carried any dirt, and it would carry dirt into the ingates and it would go into the mould. He agreed that the ideal way of running a casting was to run it both top and bottom and get the dull metal into the middle where the freezing was likely to be the last. Suction had been spoken of, but he did not think there could be any suction in a mould that had been filled. The gases in its expanded, and there was enormous pressure in the mould. The cause of the tops giving was pressure coming in from moisture or steam behind the surface. If one trickled metal down there was a chance of drying that moisture and keeping it out.

MR. H. SUMMERSGILL (Bradford) said Mr. Butterworth had mentioned scabbing, and had said in some he would run the mould down the face and some at the side. He referred to gutters for shed roofs, etc., which weighed from a few cwt. to 3 tons. These were run straight down the V-piece with a number of runners in proportion to the size of the casting—sometimes a dozen—and they very seldom had any scabbing, though they ran right down on to the face of the mould.

Reverting to the subject of risers, MR. WELFORD said he once had to make about 200 tons of docking wedges. There were 185 pairs, and no risers whatever were used, and they found no shrink on any of them. They were run slowly with metal. They were quite good and level. Judging from the outside, one could cast fairly big castings without any risers.

The CHAIRMAN, in voicing the thanks of the meeting to Mr. Butterworth, said the lecturer had certainly gone to a great amount of trouble in the preparation of the Paper.

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THE SOUTH AFRICAN SENATE has rejected the Government's Iron and Steel Bill by 17 votes to 15.

MR. J. A. PETRIE, son of Mr. D. Petrie, managing director of the Antwerp Engineering Company, Limited, has been elected a director of the company.

MR. J. J. WARREN, president of the Consolidated Mining & Smelting Company of Canada, has been elected to a seat on the board of Henry Gardner & Company, Limited.

MR. BENJAMIN TALBOT, J.P., managing-director and deputy-chairman of the Cargo Fleet Iron Company, Limited, Middlesbrough, was elected president of the National Federation of Iron and Steel Manufacturers for the year 1927-28, in succession to Mr. H. C. Bond, at the annual meeting of the Federation held in London on Thursday last. Mr. E. J. Fox, managing-director of the Stanton Ironworks Company, Limited, Nottingham, was elected as an additional vice-president.

# The Evaluation of Foundry Pig-Iron.*

BY DR. RICHARD MOLDENKE, Watchung, N.J.

The desirability of fixing upon some standard method of evaluating the quality of foundry pig-irons was first brought to the attention of the industry by the writer in a memoir presented before the American Foundrymen's Association in convention at Boston in 1902. In the year following, he elaborated the subject in a Paper read before the New England Foundrymen's Association, in which he again urged the foundrymen to take some action in view of the growing difficulties experienced with pig-irons of otherwise good composition. If an investigation of this subject was desirable then, it is certainly necessary now, in view of the post-war exigencies compelling furnacemen to cheapen production costs in every direction to remain active. The constant cry for more tonnage from the furnaces has led to the practice of surcharging the burden with high percentages of scrap bought as cheaply as possible, so that many furnaces to-day have become huge cupolas for remelting and desulphurising cast-iron scrap, while still reducing almost as much ore as heretofore in the regular way. When it is stated that scrap additions have enabled the blast furnace to effect a saving in coke of 30 per cent. and a tonnage increase of 60 per cent., the foundryman has every reason to become worried.

While nothing came of the appeal made by the writer 25 years ago, nevertheless occasionally the technical Press would record cases where foundrymen had difficulties in getting castings free from blowholes and gas phenomena, only to get out of trouble when one or more of the brands of pig-iron used were changed. The years 1921 and 1922 find articles written by J. E. Fletcher and Y. A. Dyer giving some interesting facts in this connection, and as things got worse the foundrymen of Germany appointed a committee to search for data and work out a remedy. The raising of scrap prices sufficiently to make its use unprofitable relieved this committee of its work at the time. The American Foundrymen's Association has the question up also and is planning work co-operatively with the furnace interests, and it is to be hoped that something tangible may be worked out in the not-too-distant future.

In the meantime, however, there is no immediate prospect of a solution before the foundry industry, and the use of scrap in large quantities in the blast furnace will persist no matter what is urged against it, so long as there is a dollar to be made and a market still to be had. Individual large foundry interests are consequently beginning to take cognisance of the situation and are planning to contract with satisfactory sources for "all-ore" pig-irons at special prices covering profit losses through tonnage reduction during the life of the order. After all, however, this will amount to giving a better price for a higher grade pig-iron, just as charcoal pig-iron commands a premium over the ordinary coke irons. And as necessity causes this discrimination against the ordinary run of pig-iron to-day for foundry purposes to spread, it will be part of wisdom for both foundry and furnace interests to co-ordinate these tendencies and bring them into line with the smallest possible market disturbance. This will mean a standard method of evaluating foundry pig-irons, as based upon quality.

Just what such a standard method will be when fully developed is hard to say. The foundryman of to-day tests out a car-load of some new iron by getting as much of it into his mixture as possible, repeating until he is satisfied that the sprues he recharges have acquired the characteristics of the new iron, and then makes comparative physical tests with the new as against his old-brand records. Upon the results thus obtained the new iron is either rejected or added to the list of eligible brands for the class of castings to be made. Yet, this is a crude, even if practical, way of dealing with the situation, and may work hardship to the furnace or cut out an opportunity for the foundry for good service if it happens that the test results are close to the line and the tests are not carried out by fully

* A Paper read before the Chicago Meeting of the American Foundrymen's Association.

competent men. Too many elements of uncertainty enter into the operating details and some little thing may turn the results one way or the other. Just a case in point. With a close supervision of the coke and iron ratio for cupola charging, a marked variation in the size of the pieces of coke from one day to the next will make a difference in the temperature of the iron tapped out. With dull iron, especially if carried a long distance and poured into a number of moulds from one ladle, the loss of castings is bound to be higher than if a greater liberality with the coke had given fine hot iron with a good life. The poor results thus obtained might condemn a new pig-iron, whereas the melting practice was to blame. A standard method of testing pig-iron for its quality would have to be a laboratory operation and under circumstances which permit reducing the number of variables entering into the problem to the smallest number possible and have these under reasonably accurate check control.

**Result of Change to Chemical Specification.**

The change from fracture grading to chemical control in the merchandising of pig-iron, while bitterly fought at the time, proved a blessing to the furnaces in the end, for it led to greater uniformity in product, a surer production of the compositions desired, the cutting off of the great bulk of complaints by foundrymen, the segregation of those foundrymen who might be termed hopeless for using irons by analysis, and the opening of the world as a market for pig-irons of all countries so long as the analyses were guaranteed. That this blessing has, however, proven to be not an entirely unmixed one must be laid to the fact that our present analytical methods do not give the full analysis of the iron. Were it possible at this day to add a few items to the list of the usual determinations, so that dissolved iron oxide, nitrogen, possibly hydrogen, the actual combinations existing on the part of the contained sulphur and phosphorus, an entirely different picture of the value of a pig-iron might be had. This question, though understood and worked upon, is not likely to be settled in the near future, and hence something of more immediate value in the way of a solution is required.

Perhaps no developments of interest to the grey-iron foundry brought out in recent times have such potent possibilities as the extreme superheating of cast iron and the synthetic production of that material from steel scrap. This was presented to the American Foundrymen's Association at the Detroit Convention of last year in the Paper by Prof. Piwowarsky. Apart from his highly interesting theory of graphite nuclei in molten iron of ordinary superheat being responsible for a lower physical strength, and the removal of these nuclei through intense superheating giving a much better and stronger material, the one point he did not bring out specifically is that under the extremely high temperatures prevailing in a bath of the molten metal as he wants it, there is every chance for a thorough deoxidation by the reaction between the carbon present with any iron oxide that might be in solution. Consequently, if this reasoning of the writer be true, there is a chance to correct the irons made under bad blast-furnace practice, the difficulties resulting from excessive scrap percentages in the foundry mixture, and any poor melting practice previous to the additional intensive superheating; and then to obtain a high-grade molten iron for pouring off the moulds in spite of poor-quality pig-irons. However, such a procedure involves additional expense in melting and makes the metal in the ladle more costly. Moreover, it is better practice to start with good material in the first place than later to correct that which is admittedly poor. Again, this does not solve the question of differentiating between the "all-ore" operating furnace and the one which remelts large percentages of scrap. Surely the careful and conscientious furnaceman is entitled to the best market price and the maker of low-quality metal should be penalised.

**Superheating or High-class Pig?**

So, while the indications are that the foundryman can overcome the handicap of poor foundry pig-irons by this new method of intense superheating, and further, so long as the price of scrap permits it, furnaces will—more or less—continue the practice of using it; the foundryman will find himself between the alternatives of paying extra money for getting good castings by way of intensely superheating, and also paying extra when making certain of getting high-grade foundry pig-irons. Between these two alternatives he will choose the well-made pig-iron every time, for he can then still add the high superheat if the quality of work demanded requires it.

No matter how the question is turned and considered, it comes back to working out a standard method of testing pig-iron for its quality. This may be by melting pieces of the pig-iron to be tested in an electric resistance furnace, under pyrometer control, so that no higher superheat is attained than that required for a standard pouring temperature. Then making test bars and testing them for comparison with similar tests with the bars from other known brands of pig-iron for that particular foundry. This naturally involves the effect of the chemical composition upon the physical properties brought out by the tests. In such a method, with the standardisation of the degree of superheat attained, a standard pouring temperature; with standard test bars and moulds in which they are made, standard physical tests and analytical results, there remain practically only the gathering of data and their study to interpret such test results into quality measures of foundry pig-iron. This is no small work and would engage the attention of foundry and furnace metallurgists and engineers a long time. Possibly some other, better way can be suggested to replace the present cut-and-try method by way of the cupola, but that something must be done about the situation, and that without great delay, is patent to every close observer of the trend of blast-furnace practice so far as the production of foundry pig-irons is concerned.

## Correspondence.

*[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]*

**Progress in Ironfounding.**

*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—I have just had brought to my attention the leading article in your issue of June 2, entitled, "Progress in Ironfounding," and should like to thank you for your discriminating notice of my James Forrest Lecture. In view of what you say as to my having given "only one example of real advance in the foundry world" (pearlitic cast iron), I would like to say that I do not by any means consider that this is the only scientific advance to which it is worth while calling attention during the period reviewed by me. I chose pearlitic cast iron as an illustration because it is undoubtedly a very important scientific discovery which has a great bearing on engineering practice. The reason why I limited myself to one example was simply that I was covering the entire field of metallurgy and could not devote more time to the foundry. I had the choice of two methods—either I could take one really good example and describe it in some detail, or I could take several examples and treat them briefly. It appeared to me, on considering the matter carefully, that the former was the preferable method because although I limited myself to a comparatively small number of examples I gave each of them in sufficient detail to enable an engineer to understand what I was talking about.

Yours, etc.,
H. C. H. CARPENTER.

Royal School of Mines,
South Kensington, London, S.W.7.

THE BOARD of the Bengal Iron Company announce that the result of the year's trading, so far as at present ascertainable, appears to be such as will permit of the debit balance of £96,072 being wiped out, and at least one year's arrears of preference dividend being paid not later than October next.

XUM

# The Phenomenon of Temper-Hardening in Steels.*

By Tokujiro Matsushita and Kiyoshi Nagasawa (Tokio, Japan).

(*Abridged.*)

In 1922 one of the authors (T. Matsushita) published a Paper in the Science Reports of the Tôhoku Imperial University on "The Magnetic Hardness of Quenched Steels," in which he recommended the measurement of the magnetic hardness as a useful method for examining heat-treated steels. He also pointed out that it could be used for determining the mechanical hardness of steels, because those two hardnesses ran parallel to each other.

In the present investigation it was originally intended to examine in detail, by means of the magnetic hardness, the effect of the tempering of quenched steels at various temperatures. In the course of the experiments, it was found that the magnetic hardness of quenched carbon steels first decreased with the rise of the tempering temperature, but that from a temperature of 400 to 450 deg. C. it began to increase, and attained a maximum at 475 to 550 deg. C., then decreasing again as the tempering temperature increased further. That increase of magnetic hardness caused by tempering is here called "temper-hardening." The phenomenon is accompanied by corresponding changes in the mechanical properties.

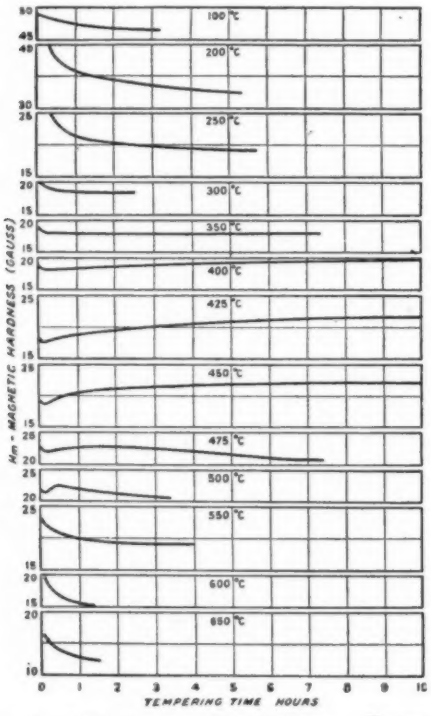



FIG. 1.—0.75 PER CENT. CARBON STEEL. EFFECT OF THE TIME OF TEMPERING ON THE MAGNETIC HARDNESS.

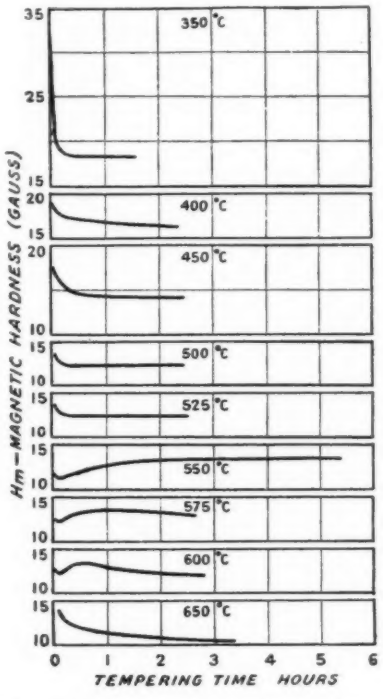



FIG. 3.—NICKEL-CHROMIUM STEEL. EFFECT OF THE TIME OF TEMPERING ON THE MAGNETIC HARDNESS.

Experiments were first made with a straight-carbon steel having the following chemical constitution:—Carbon 0.75, silicon 0.25, manganese 0.22, phosphorus 0.024, and sulphur 0.030 per cent. Thirteen cylindrical specimens, 10 cm. long and 8 mm. in diameter, were taken from a round rolled bar. They were quenched in water from 800 deg. C., and their magnetic hardness was

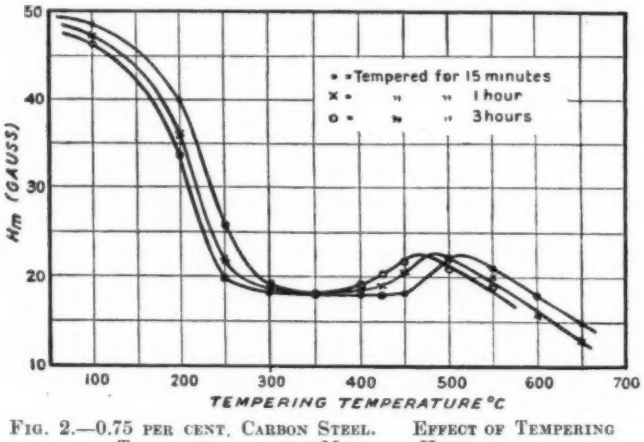



FIG. 2.—0.75 PER CENT. CARBON STEEL. EFFECT OF TEMPERING TEMPERATURE ON THE MAGNETIC HARDNESS.

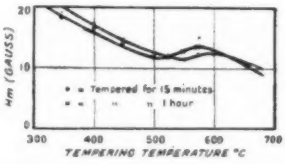



FIG. 4.—NICKEL - CHROMIUM STEEL. EFFECT OF THE TEMPERING TEMPERATURE ON THE MAGNETIC HARDNESS.

* Read before the Annual Meeting of the Iron and Steel Institute.

measured by a magnetometric method. They were then tempered at 100, 200, 250, 300, 350, 400, 425, 450, 475, 500, 550, 600, and 650 deg. C. for a prolonged period in an electric resistance furnace. During the tempering the specimens were taken out of the furnace from time to time, and their magnetic hardness measured.

The results of the experiments are reproduced graphically in Fig. 1. The values of the magnetic hardness are represented by the coercive force measured in gausses.

Attention is specially directed to the curves corresponding to tempering temperatures in the vicinity of 450 deg. C. When tempered below

A similar result was also obtained by Maurer for a 0.83 per cent. carbon steel.

The authors made the same experiments with a nickel-chromium steel, the chemical composition of which was: Carbon 0.32, silicon 0.17, manganese 0.35, phosphorus 0.014, sulphur 0.011, nickel 2.81, and chromium 0.90 per cent. The specimens were first quenched in oil from 850 deg. C. The experimental results are given in Figs. 3 and 4. From the curves it will be seen that the effect of tempering on the magnetic hardness of quenched nickel-chromium steel is the same as on that of carbon steels, the only difference being the point of occurrence of the maximum hardness.

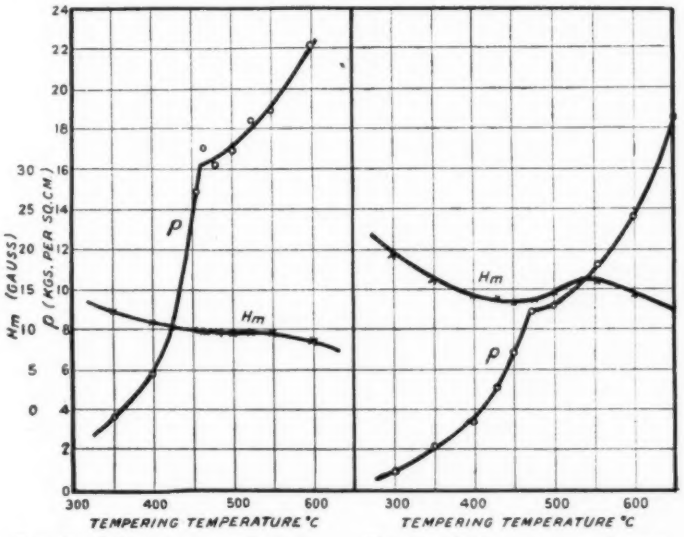



FIG. 5.—0.24 PER CENT. CARBON STEEL.




FIG. 6.—0.45 PER CENT. CARBON STEEL.

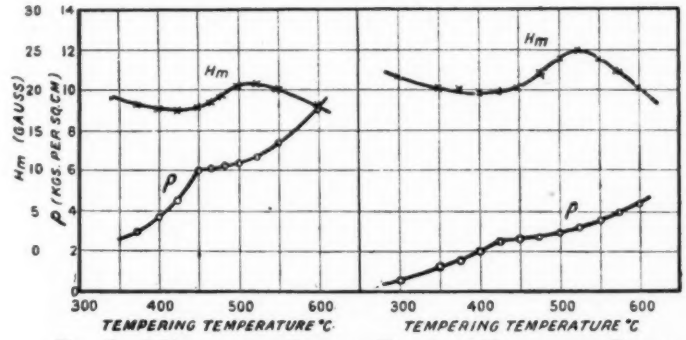



FIG. 7.—0.64 PER CENT. CARBON STEEL.




FIG. 8.—0.80 PER CENT. CARBON STEEL.

EFFECT OF THE TEMPERING TEMPERATURE ON THE IMPACT TEST AND MAGNETIC HARDNESS.

400 deg. C., the magnetic hardness decreases with the lapse of time, tending towards an asymptotic value; on tempering at 425 deg. C., however, the magnetic hardness diminishes at first, and then begins to increase very slowly with time, reaching a maximum in ten hours. The time required to attain the maximum hardness varies inversely with the tempering temperatures. If the tempering be prolonged beyond that point, the hardness decreases gradually in all cases. On tempering above 550 deg. C., there is only a gradual decrease of the magnetic hardness.

The curves in Fig. 2 show the relation of the magnetic hardness to the tempering temperature, with tempering periods of fifteen minutes, one hour, and three hours. The curves are similar to each other, but as the time of tempering increases they are displaced towards lower temperatures. The curves show that the magnetic hardness of quenched carbon steels first decreases as the tempering temperature is raised to about 400 deg. C., and then increases to a maximum at about 500 deg. C., after which it decreases gradually with a further increase of the tempering temperature.

*Impact Tests.*—It seemed highly probable that in association with the abnormal change in the magnetic hardness other physical properties would also vary abnormally. As a first experiment, impact tests were made, as that means of investigation is very sensitive to a slight change in the properties of a metal. Four straight carbon steels, a nickel steel, and a nickel-chromium steel were tested. The chemical compositions of these steels are recorded in Table I:—

TABLE I.—*Test Specimens used in Impact Tests.*

| Material. | Carbon. | Silicon. | Manganese. | Phosphorus. | Sulphur. |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| Carbon steel .. | 0.24 | 0.21 | 0.38 | 0.028 | 0.029 |
| ,, ,, | 0.45 | 0.29 | 0.43 | 0.024 | 0.030 |
| ,, ,, | 0.64 | 0.18 | 0.39 | 0.025 | 0.013 |
| ,, ,, | 0.80 | 0.39 | 0.39 | 0.023 | 0.010 |
| * Nickel steel | 0.43 | 0.28 | 0.62 | 0.012 | 0.011 |
| † Nickel-chromium steel.. | 0.32 | 0.16 | 0.39 | 0.014 | 0.013 |

* Nickel, 3.65 per cent. † Nickel 2.78 and chromium 0.84 per cent.

The tests were made on a 30-kg.-meter Charpy machine, Mesnager's type of test-piece being used. The range of tempering temperature tested was restricted to 100 deg. C. on either side of the temperature of maximum temper-hardening, and in this range ten observations at intervals of from 15 to 25 deg. C. were made. Special precautions were taken to ensure that the test-pieces were in the same condition as nearly as possible. They were prepared from a single rolled bar, and were heat-treated in the same way by heating them simultaneously in an electric resistance furnace at a uniform temperature, and quenching them in

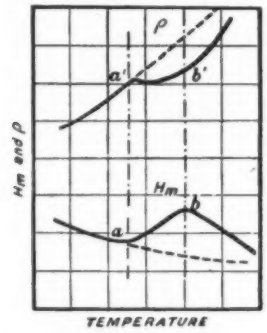



FIG. 9.—COMPARATIVE CURVES OF THE MAGNETIC HARDNESS AND THE IMPACT RESISTANCE.

a bath of water kept at a constant temperature of 14 deg. C. During the tempering, the temperature was never allowed to fluctuate more than 2 deg. C. from the prescribed value. After tempering, the test-pieces were allowed to cool in air. The temperature was measured by a platinum, platinum-rhodium thermocouple.

For the first heat treatments, the test-pieces used were of twice the normal length required for impact testing (the dimensions being 10 × 10 × 55 mm.), for the sake of convenience in that

ing and finishing points of the abnormality on the magnetic hardness curve—agree very well with the similar points $a'$ and $b'$ on the impact resistance curve.

In the impact resistance curve, above the "knee," the slope of the curve becomes less steep, indicating that in the range the steel is some-

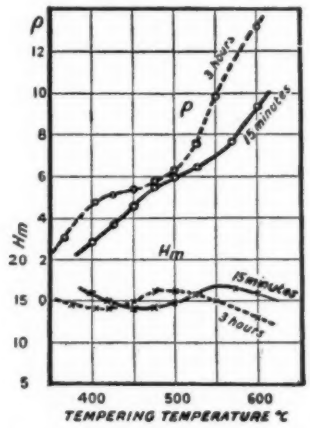



FIG. 10.—CARBON STEEL. EFFECT OF THE TIME OF TEMPERING ON THE IMPACT RESISTANCE AND MAGNETIC HARDNESS.

what brittle, but as the temperature rises further the curve rises more rapidly, showing the softening effect of high temperatures. So far as the straight-carbon steels are concerned, the abnormal changes of the magnetic hardness and of the impact resistance increase with the carbon contents.

The effect of the time of tempering on the impact resistances of a 0.45 per cent. carbon steel, a nickel steel, and a nickel-chromium steel was next investigated, and the dotted lines in

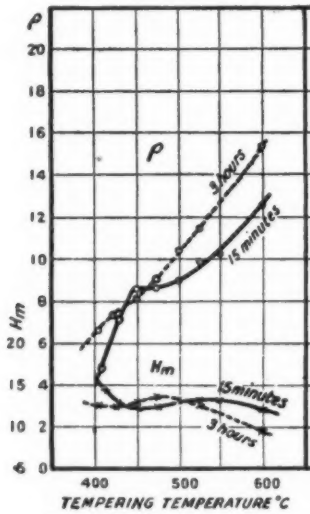



FIG. 11.—NICKEL STEEL.

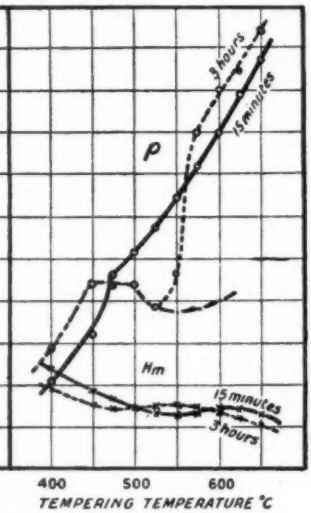



FIG. 12.—NICKEL-CHROMIUM STEEL.

EFFECT OF THE TIME OF TEMPERING ON THE IMPACT RESISTANCE AND MAGNETIC HARDNESS.

operation and in the measurement of the magnetic hardness. After the magnetic hardness had been measured, the test-pieces were cut in two and subjected to the impact test.

The curves for the impact resistance ($\rho$), as well as those for the magnetic hardness, are given in Figs. 5, 6, 7, and 8. On examining these curves, a similar abnormal change in the impact resistance is to be seen, corresponding to the variation of the magnetic hardness. In Fig. 9 the general relation between these two sets of curves is shown to demonstrate more clearly the close correspondence of the abnormal changes of the two properties. Points $a$ and $b$—the start-

Figs. 10, 11, and 12 show the curves for tempering periods of fifteen minutes and three hours, followed by air cooling.

In carbon, nickel, and nickel-chromium steels, both the maximum point on the curve of magnetic hardness and the "knee" in the impact resistance curve are displaced towards lower temperatures as the tempering period increases. For nickel-chromium steel, the impact curve has also a peculiar form; it shows a conspicuous minimum at 530 deg. C., and if the test-piece be cooled very slowly in the furnace instead of in the air, the curve takes the course shown by a "chain" line. This phenomenon is usually known

as " temper-brittleness," of which a special investigation will be reported in the near future.

*Tensile Tests.*—These were made on carbon and nickel steels, the chemical compositions of which

TABLE II.—*Composition of Test Specimens used in Tensile and Brinell Tests.*

| Material. | Carbon. | Silicon. | Manganese. | Phosphorus. | Sulphur. |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Carbon steel .. | 0.25 | 0.23 | 0.29 | 0.013 | 0.017 |
| ,, ,, | 0.40 | 0.21 | 0.36 | 0.021 | 0.030 |
| *Nickel steel | 0.40 | 0.22 | 0.54 | 0.014 | 0.013 |

* Nickel, 3.58 per cent.

are given in Table II. In the preparation of the test-pieces the same care was taken as in the case of the impact tests. The middle part of the test-pieces was turned down to 10 mm. in diameter, the gauge-length being 72.4 mm.; two tests were made for every tempering temperature, and the mean was taken as the final result. The experimental results are recorded graphically in Figs. 13, 14, and 15, from which it will be noticed that an abnormal change was also observable in the tensile properties corresponding to the abnormalities found in the magnetic hardness and the impact resistance.

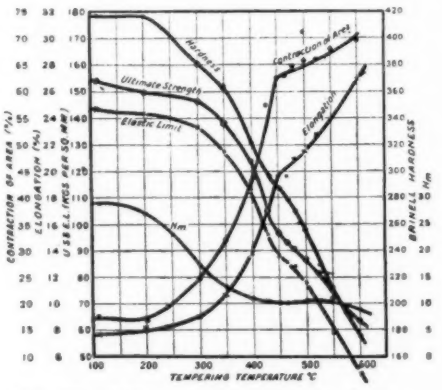



FIG. 13.—0.24 PER CENT. CARBON STEEL.

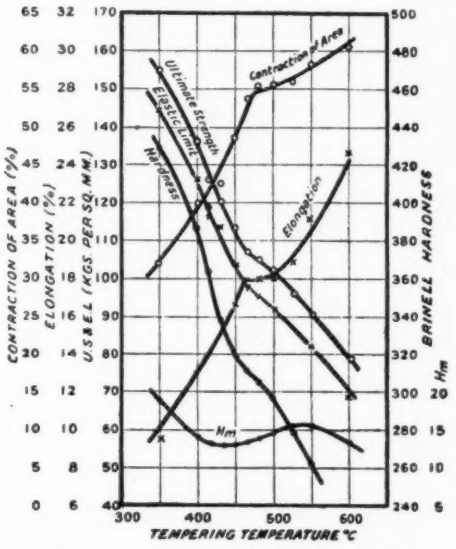



FIG. 14.—0.40 PER CENT. CARBON STEEL.

RELATION BETWEEN MAGNETIC HARDNESS AND TENSILE TESTS.

*Brinell Hardness Tests.*—These were made on the same steels used for the tensile tests, and the results are included in Figs. 13, 14, and 15. The curves show a similar abnormal change corresponding to that of the magnetic hardness. Hitherto it has been generally believed that the curves showing the alteration of the mechanical properties of steels with the tempering temperature were of a smoothly descending type and did not exhibit any abnormalities corresponding to the phenomenon of temper-hardening. This phenomenon, which is fully confirmed by the present investigation, is, however, very important when considering the effect of the tempering temperature on the mechanical properties of quenched steels.

*Cause of Temper-Hardening.*—In the opinion of the authors, the cause of this hardening is the disintegration or refining of iron crystals taking place before crystal growth begins. This phenomenon, called " recrystallisation," is associated with the release of internal strains by virtue of the rise of temperature. The internal strain is, of course, due to the formation of martensite during quenching. In what follows, several facts which favour the above conclusion will be given.

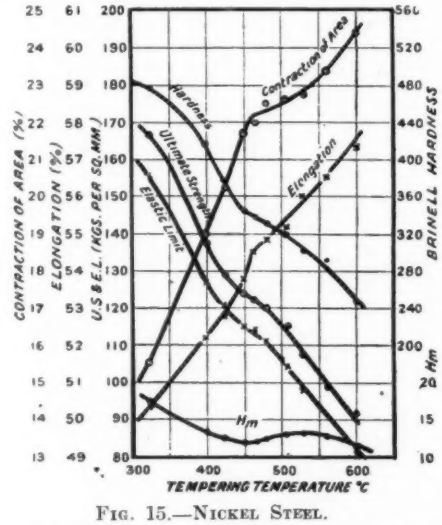



FIG. 15.—NICKEL STEEL.

RELATION BETWEEN MAGNETIC HARDNESS AND TENSILE TESTS.

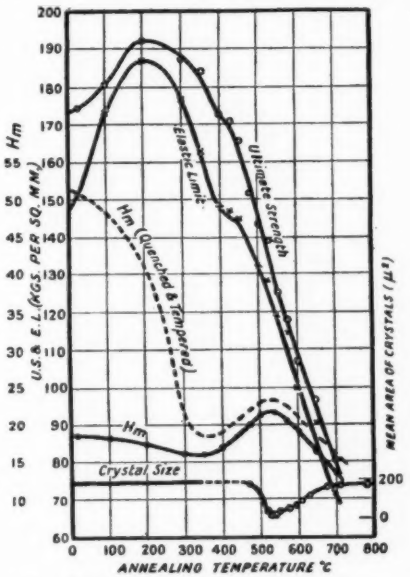



FIG. 16.—PIANO WIRE. THE RELATION BETWEEN THE MAGNETIC HARDNESS, TENSILE TESTS, AND CRYSTAL SIZE.

(i) It is already established by experiment that in cold-worked iron and steel internal strain can only be removed by annealing above 500 deg. C. It is also well known that martensite is completely tempered at 300 to 350 deg. C.; hence it is conceivable that after the complete removal of the martensitic structure the greater part of the

strain still remains unreleased. The fact that notwithstanding the decomposition of the martensite by tempering, the hardness of quenched steel does not decrease considerably is due on the one hand to the fineness of the troostite grain, and on the other hand to the persistence of the internal strain up to 500 to 550 deg. C. The temper-hardening is due to the refining or recrystallisation of the iron crystals favoured by the presence of the internal strain.

(ii) In cold-worked steels, the abnormal change of the mechanical and magnetic hardnesses produced by tempering at various temperatures is quite similar to that in quenched steels, as the following example will show. A cold-worked piano wire, the composition of which was carbon 0.79, silicon 0.28, manganese 0.39, phosphorus 0.031, and sulphur 0.027 per cent., was tested in the manner described above. The results are shown graphically in Fig. 16, from which it will be seen that the tensile strength and the elastic limit increased considerably at first by tempering, attaining a maximum at about 200 deg. C.; beyond that they rapidly decreased. As is well known, this initial increase is due to the removal of the great instability caused by the cold-working. The subsequent decrease is, of course, due to the softening effect of the higher temperature. At 400 deg. C. the beginning of the abnormal change corresponding to the temper-hardening above referred to is observable, and is due to recrystallisation. In the same range the increase of the magnetic hardness is also observable. The dotted line in the same figure shows the magnetic hardness in the sample when quenched and tempered.

The lowest curve in Fig. 16 represents the results obtained by Chappel when a cold-drawn wire was annealed at various temperatures, and the corresponding mean area of microcrystals was measured. It was very interesting to observe that the minimum of the "mean area—annealing temperature" curve coincides with the maximum of the hardness curve. There is thus a close resemblance between the changes of the mechanical properties caused by the tempering of steels in the cold-worked and in the quenched conditions.

(iii) It is already well known that cold-worked steels undergo recrystallisation on annealing. The temperature of recrystallisation is affected by several factors, such as the chemical constitution, the internal strain, etc., and its determination is usually very difficult. If, however, the above views regarding temper-hardening are correct, the recrystallisation temperature can be obtained from the "magnetic hardness—tempering temperature" curve, and this convenient method would become of great use in physical metallurgy.

It is interesting to note that the yielding temperature of steels—that is, the temperature at which intercrystalline slipping occurs—lies close to the temperature of recrystallisation, as was previously reported by one of the present authors.

## Cast-Steel Cable Chain.

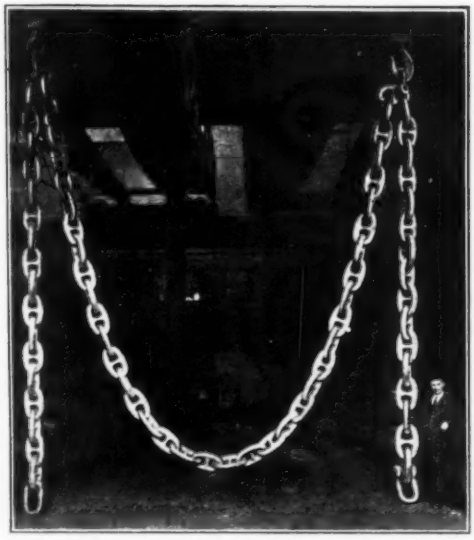
Chains in iron have been known practically since that material was first forged, and they have all, of course, been liable to the human element in the weld necessary in every link. The softness of the material to ensure that as perfect a weld as possible will be made has, to a considerable extent, affected their useful life. Proposals have been made from time to time to manufacture these chains in cast steel.

These proposals interested the Admiralty, and various firms tackled the problem experimentally, but it has been left to the Beardmore Foundry to produce a finished cast-steel chain which would pass the rigid test requirements laid down. The specification called for a 12½-fathom 3-in. cast-steel stud-link chain, with the necessary shackle. A testing length was to be selected by the inspector anywhere from the finished chain and subjected to the following tests:—

*Shock Test.*—Two single-links each were to stand 15 blows with a 1-ton tup without sign of fracture as follows: 2 blows at 10 ft., 2 blows at 15 ft., 11 blows at 20 ft. A three-link sample from the test length was to stand without sign of fracture a proof load of 204 tons, the overall elongation not to exceed 1 in. at this load. The sample was then to be loaded till fracture occurred, and to give a breaking load of not less than 306 tons. The whole chain was then to stand a proof load of 204 tons. The high standard required can be understood by considering beside these figures the corresponding tests required on a standard 3-in. wrought-iron cable chain, *i.e.*, proof load, 145.8 tons; breaking load, 218.7 tons. It will be noticed that the proof load stipulated for the cast-steel chain is nearly the breaking load accepted for the wrought-iron chain.

A complete chain was manufactured for the Admiralty which fulfilled all their test requirements. This chain is at present in service, and the result of its performance is awaited with interest.

The test results as taken by the Admiralty showed 36.5 tons per sq. in. tensile, 25 per cent. elongation, 180 deg. bend, W.F. The 1-ton tup test on two links resulted in an elongation of 2¼ in., whilst the proof and breaking loads applied to the three-link sample and the completed chain at Lloyd's Proving House, Netherton, were as follow: (1) Proof load of 204 tons applied, no fracture; total elongation, $\frac{12}{32}$ in.; (2) load increased to 306 tons, no fracture; total elongation 2⅜ in.;



LARGE STEEL CABLE CHAIN CAST IN THE FOUNDRY OF WM. BEARDMORE & COMPANY, LIMITED.

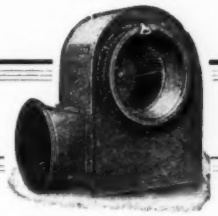
(3) load further increased to 385 tons, not broken; (4) load further increased to 400 tons, not broken; total elongation 6⅜ in. As 400 tons is the maximum testing capacity of the machine, it was not possible to break this sample, and no other testing machine is available for this purpose.

The Admiralty proof load of 204 tons was applied to the completed chain without fracture. The total extension of the chain at this load was 15½ in. measured on a length of 73 ft.

The above particulars are extracted from the house organ of Wm. Beardmore & Company's establishment.

IT HAS BEEN reported of late that the Spanish Government are now taking steps towards the reorganisation of the lead industry. Consumption in Japan and the United States having fallen off a good deal lately, North American producers are more dependent on the European market for an outlet, and this, of course, aggravates the depression on this side.

CONSUMPTION OF COPPER, considering conditions in this country and Germany, is by no means bad, while some little improvement has become manifest in the demand from France. At its present level the market should display resistance to adverse outside influences of a financial character, while it is interesting to note that there has been a continuous depleting going on in the stocks of rough standard bars held in this country, further consignments having been shipped across the Atlantic for conversion.



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## Trade Talk.

THE HUNSLET ENGINE COMPANY, LIMITED, have received from the L.M.S.R. Company a further order for 25 of the latest type of tank locomotives.

MR. JOSEPH H. HAINSWORTH, 1, Dalton Road, Coventry, iron, steel and scrap metal merchant, has removed to White House, Morningside, Coventry.

AUTOMATIC AND ELECTRIC FURNACES, LIMITED, Elecfurn Works, 173-175, Farringdon Road, London, E.C.1, have entered into an arrangement with G. Blundell & Company, Limited, of Yokohama, for the sale of the Wild-Barfield electro-magnetic furnaces in Japan.

WILLIAM GEIPEL, LIMITED, formerly Wm. Geipel & Company, Vulcan Works, St. Thomas Street, London, S.E.1, are removing to new and larger premises in three or four weeks' time at 156-170, Bermondsey Street, S.E.1. These premises will also be known as the Vulcan Works.

MR. FRED W. DAVIES has relinquished his position as manager to T. W. Broadbent, Limited (which he has held for more than 20 years), and has established himself in business at the Electrical Maintenance Works, Colne Road, Huddersfield. Mr. Davies intends to carry on a general consulting practice, together with the electrical maintenance business.

THE MIRRLEES WATSON COMPANY, LIMITED, announce that the fire which occurred at their works on Monday, June 6, was much less serious than reported at the time. It was confined to a certain number of patterns stored in open yard. The main pattern stores and the pattern shop were practically untouched. No machinery was affected, and the works continued in full operation without interruption.

COX & DANKS, LIMITED, 168, Regent Street, London, W.1, who are engaged on the salvage of the scuttled ex-German Fleet at Scapa Flow, were successful on June 10 in raising the 23,000-ton ex-German battle cruiser "Moltke." This vessel has lain keel uppermost with a list of 16½ deg. to starboard in 72 ft. of water since she was scuttled on June 21, 1919. It is a great achievement, accomplished after many months of attempt and disappointing efforts, and is considered to be one of the greatest, if not the greatest, salvage feats in the world. The vessel is now being towed to the Island of Cava, where she will be completely dismantled and broken up.

THE WHITEHEAD IRON AND STEEL COMPANY, LIMITED, Tredegar, have resolved to increase the ordinary share capital from £204,210 to £260,000, and to capitalise £51,052 of the general reserve, which is to be distributed to the ordinary shareholders as a bonus, in the ratio of one share for every four held. In order to facilitate this, the final instalment of 2s. 6d. per share on the partly paid ordinary shares has been called up and paid. During the year the whole of the outstanding 6 per cent. second debentures have been redeemed. In spite of the industrial troubles the output for the year is the best recorded. The new semi-continuous bar and rod mill at the Newport works, which went into commission last August, has proved completely successful, and the reconstruction of the heating equipment in a similar mill at the Tredegar Works has considerably increased the output of that plant.

MR. HENRY J. FREYN, president of the Freyn Engineering Company, has signed in Moscow, Russia, what is believed to be the largest single consulting engineering contract ever negotiated. By the agreement the Union of Soviet Socialist Republics retains the Freyn Company for general consultation on all iron and steel plants and their construction for five years, starting July 1, 1927, says the "Daily Metal Trade." The activities engaged by the Soviet Republic, which contemplates a 5-year programme, involving approximately $350,000,000 (£70,000,000), include consultation, projection of plans, detailed drawings, and supervision of construction. Compensation is fixed at a definite percentage, as yet unknown, of the construction costs, with a guaranteed consultation minimum. The plans provide for new plants with an annual capacity of 750,000 tons of ingots each. Construction of these units will cost between $40,000,000 and $75,000,000 (£8,000,000 and £15,000,000) each. The first unit is to be in the Kunitz basin of the Yenesei valley, south-east of Novosibirsk; the second in the Magnitnaya district of the Ural mountains, and the third in the Krivoirog district of the Ukraine.

**An Induction Furnace without Iron.**—At the recent general meeting of the Association of German Chemists Dr. von Bersnder, of Berlin, described an electric induction furnace without iron or electrodes in which the electric current is produced by high-frequency currents. For temperatures of over 1,200 C. such a high-frequency furnace—the author stated—was superior to all others as regards clean working.

## Company Meeting.

**Sir W. G. Armstrong, Whitworth & Company, Limited.**—MR. J. FRATER TAYLOR, who presided at the annual meeting of this company, said that, after charging the full amount of interest, whether it had to be paid or not, the result was a net loss for the year before depreciation of £531,210 1s. 1d. But that was not all the loss—they were compelled to face and to write off £833,573 16s. 6d. of special losses, mainly incurred on civil engineering ventures. As the report stated, they were enabled to provide for those special losses through the sale of certain of the company's investments. Taking 1926 results alone, there was, however, an important mitigating circumstance. He referred, of course, to the coal strike. Had it not been for the coal strike, profits for 1926 and for the early part of 1927 would have been very much better. It was difficult to measure the exact damage done by the strike in question, but fuel and power alone cost over £70,000 extra. They were aware that through circumstances entirely beyond their control there was much less armament business to go round. Very serious study had been and was being given to that phase. If it were possible to develop new lines of business without entrenching upon already well-established lines the problem would be less difficult, but new lines were not easy to find, and new businesses were expensive to establish, so that they were necessarily driven to examining possibilities which were close at hand. Included in those arrangements were closer working arrangements with their neighbours, Vickers, Limited. It might be that in such arrangements a way would be found which would be mutually beneficial, but all that he was able to say was that conversations were taking place.

## Company Reports.

**Larmuth and Bulmer, Limited.** — Depreciation, £2,494; net trading results, £4,714; no ordinary dividend.

**Ebbw Vale Steel, Iron & Coal Company, Limited.**—No dividend on 7 per cent. cumulative preference shares or on ordinary shares.

**Falkirk Iron Company, Limited.**—Final dividend, 5 per cent. actual, making 10 per cent. for year; carry forward, £35,596; reserve, £10,000.

**J. Hetherington & Sons, Limited.**—Net profits, £35,691; preference dividend paid, but no distribution on ordinary shares; balance carried forward, £7,599.

**Whitehead Iron & Steel Company, Limited.**—Profit, £50,136; final dividend, 9 per cent., making 15 per cent. for year; reserve, £11,052; carry forward, £14,401; brought in, £4,039.

**Richard Johnson, Clapham & Morris, Limited.**—Net profit, £20,077; brought forward, £8,199; dividend on ordinary shares for year, 3¾ per cent. per annum (less tax); carry forward, £13,824.

**Mirrlees, Bickerton & Day, Limited.**—Net profit, £17,713; brought forward, £21,245; available, £38,958; dividend, 6 per cent. per annum, less tax, for year on ordinary shares; reserve, £2,308; carry forward, £11,158.

**Manley and Regulus, Limited.**—Profit, £29,577; brought in, £6,608; general reserve, £10,000; reserve for equalisation of dividends, £10,000; final dividend on ordinary shares, 1s. 6d. per share, less tax, plus bonus 5 per cent., also less tax; forward, £5,221.

## New Companies.

**British Secheron Company, Limited,** 525, Abbey House, Westminster, S.W.—Capital £4,000 in £1 shares. Agents, factors, etc., of electrical and general engineering plant and machinery. Directors: F. M. T. Lange, 35, Gloucester Gardens, Hyde Park, W.2; W. Richardson, 6, Christchurch Road, Surbiton Hill; and G. Meyfarth, 31, Avenue Blanc, Geneva.

**Carter Bros. (Liverpool), Limited,** 1, Buckingham Street, Liverpool.—Capital £5,000 in 10s. shares. Metallic packing manufacturers. Directors: C. W. Carter and I. Adamson.

**Marsden & Stansfield, Limited,** Central Brass and Iron Works, Brighouse, Yorks.—Capital £10,000 in £1 shares. Engineers, ironfounders, etc. Directors: W. Marsden, Glen Royd, Halifax Road, Brighouse, Yorks; and W. Stansfield, 32, High Street, Brighouse. Secretary: W. Marsden.

**Poole Foundry, Limited.**—Capital £500 in £1 shares. To acquire business carried on by W. E. Stephens and R. J. Bishop, at 10, Thames Street, and the Quay, Poole, as the Poole Foundry.

**Rogers & Thompson, Limited,** 41, North John Street, Liverpool.—Capital £100 in £1 shares. Engineers. Directors: A. Rogers and J. Thompson.

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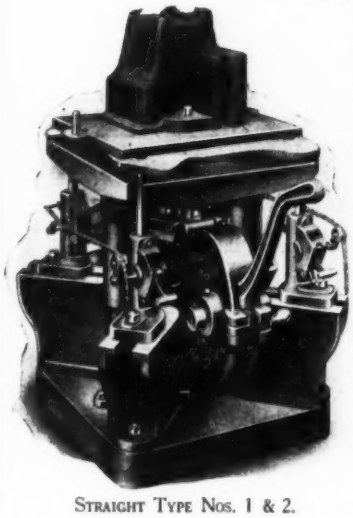

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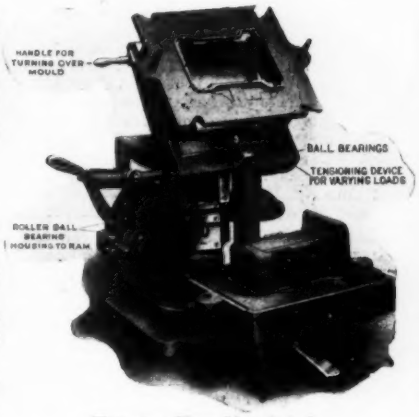


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# IRON AND STEEL MARKETS.

## Pig-iron.

**MIDDLESBROUGH.**—Although any improvement in the home demand for Cleveland iron is scarcely perceptible at the moment, the tone of the Tees-side markets is certainly more hopeful than has been the usual experience of late, the recent cut in prices having had a beneficial effect where outside competition is concerned. It is, in fact, no longer cheaper for local consumers to buy from the foreigner, and consequently these orders from Cleveland buyers will not now be sent out of the country. That is one substantial gain. Another is that the export trade is improving. Shipments to foreign ports are expanding, the total exports of pig-iron from the Tees to the 14th inst. being 8,277 tons, compared with 4,123 tons to May 14. Meantime, quotations remain firm and unchanged as follow:—No. 3 Cleveland G.M.B., 70s. per ton; No. 1 Cleveland foundry iron, 72s. 6d.; No. 4 foundry, 69s.; No. 4 forge, 68s. 6d. per ton.

**LANCASHIRE.**—Local demand for foundry pig is fairly well maintained, current quotations ruling about as follow:—For delivery into this area, 79s. per ton for Derbyshire, 79s. 6d. for Staffordshire, 83s. for Cleveland, 97s. 6d. for Scottish, and about 92s. 6d. for East and West Coast hematites.

**THE MIDLANDS.**—A little more business has been reported in pig-iron recently, due possibly to the suspension of ordering just prior to the holidays. There is, however, little forward buying, although prices are getting very near to pre-strike level. Northants No. 3 can be purchased at 65s., and Derbyshire generally is 70s. per ton at the furnaces, showing a reduction of 2s. 6d. on the previous week's figures.

## Metals.

**Copper.**—Current conditions in most base metal sections continue unsatisfactory as regards the volume of business negotiated during the past week, which evidenced a somewhat sharp reaction in standard copper towards the close. The position is rather difficult to explain, considering that quotations in America have been shaded to only a slight extent. The Continental demand has failed to develop to any notable extent, in spite of the recent more optimistic reports from across the Atlantic.

Official closing prices of standard copper have been as follow :—

*Cash*: Thursday, £53 16s. 3d. to £53 17s. 6d.; Friday, £53 17s. 6d. to £53 18s. 9d.; Monday, £53 17s. 6d. to £54; Tuesday, £53 15s. to £53 16s. 3d.; Wednesday, £53 15s. to £53 17s. 6d.

*Three Months*: Thursday, £54 8s. 9d. to £54 10s.; Friday, £54 11s. 3d. to £54 12s. 6d.; Monday, £54 10s. to £54 11s. 3d.; Tuesday, £54 7s. 6d. to £54 8s. 9d.; Wednesday, £54 7s. 6d. to £54 8s. 9d.

**Tin.**—Movements in the market for cash tin have taken a further upward turn, despite adverse influences, and at the moment this is by far the strongest section in the market. The scarcity of actual supplies continues an important factor, while the home stocks have been reduced again by 233 tons, with only 131 tons held in London and 1,073 tons at Liverpool. These stocks are dangerously low, and the same applies to New York.

Official closing prices of standard tin have been as under :—

*Cash*: Thursday, £294 10s. to £294 12s. 6d.; Friday, £295 10s. to £295 12s. 6d.; Monday, £296 5s. to £296 10s.; Tuesday, £295 17s. 6d. to £296; Wednesday, £298 10s. to £298 15s.

*Three Months*: Thursday, £286 to £286 5s.; Friday, £286 17s. 6d. to £287; Monday, £286 to £286 5s.; Tuesday, £285 10s. to £285 15s.; Wednesday, £286 5s. to £286 10s.

**Spelter.**—Owing to a limitation in volume of home consumptive demand, business in ordinary spelter has been on a restricted scale, although values remain fairly steady on the whole. In view of the course of the American market and the absence of any bullish features here, the June figures are awaited with more than the usual interest.

The following are the week's prices :—

*Ordinary*: Thursday, £28 15s.; Friday, £28 11s. 3d.; Monday, £28 11s. 3d.; Tuesday, £28 10s.; Wednesday, £28 8s. 9d.

**Lead.**—The market for soft foreign pig is again depressed, showing a fall in values for prompt delivery, this movement being a reaction from the artificially high level brought about recently by free repurchases by the short interest. The position remains affected by the existence of a heavy surplus of supplies at this end, which may not be dispersed for some time.

The week's prices are appended :—

*Soft foreign (prompt)*: Thursday, £24; Friday, £24 2s. 6d.; Monday, £24 3s. 9d.; Tuesday, £24 2s. 6d.; Wednesday, £24 5s.

## Pneulec Royer to be Demonstrated in Sheffield.

We are advised that from July 4 to 16 the Pneulec Royer sand-mixing machine will be demonstrated in Sheffield. It will be noticed that these dates include the period of the Convention of the Institute of British Foundrymen, which this year is being held in Sheffield.

The Pneulec Royer is one of those machines which must be seen in operation before any definite idea as to the possibilities of the machine can be formed, and Pneulec have decided that the Convention time is rather an appropriate time to have a demonstration in Sheffield.

All foundrymen are invited to call and see the No. 1 size machine, which is being demonstrated. Mr. Lines, Pneulec Works representative, will be in attendance, and the demonstration is being held at the Wicker Arches offices of the General Refractories Company, Limited.

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